AN ANALYSIS OF EVAPORATION AT LAKE HEFNER, 1965-1966, BASED ON THE WATER BUDGET, ENERGY BUDGET, AND EVAPORATION TANKS

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CHAPTER I

INTRODUCTION

In the state of Oklahoma the average annual rainfall decreases from 54 inches at the eastern edge of the state to 16 inches at the western edge of the panhandle. Moreover, the estimated potential evaporation from free water surfaces increases from about 48 inches at the eastern edge of the state to 66 inches at the southwestern corner of the state (31)*. In about three-quarters of the state the potential evaporation exceeds rainfall. In other more arid states the potential loss of water due to evaporation is even higher. The total annual losses of water due to evaporation in the 17 western states have been estimated at 23,641,000 acre feet (31). Thus, the importance of evaporation to a society concerned with fresh water conservation can hardly be overestimated.

At the present time a great need exists for an accurate method of measuring evaporation from large lakes. This need exists both because of the need of hydrologists to know the evaporation losses when planning water resources projects, and because of the current interest in evaporation suppression by monolayer forming chemicals. At present, the most accurate method of measuring evaporation is by means of the water budget. Unfortunately, very few lakes have a water budget accurate enough to

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*Number in parentheses refers to the bibliography.

use for evaporation determination because of problems of high withdrawal rates, seepage, and inflow from runoff. A second, less reliable method of estimating evaporation is the energy budget method. Both methods were used at Lake Hefner and are discussed in detail in this dissertation.

Lake Hefner is a 2550 acre lake approximately circular in shape and located on relatively high ground at the extreme northwestern edge of Oklahoma City. Because of an exceptionally accurate water budget, Lake Hefner was used for evaporation studies in 1950-51 and for evaporation suppression studies in 1958.

The present study, which was supported by U.S. Bureau of Reclamation Contract 14-06-D-5629, was carried out at Lake Hefner during the warm months of 1965 and 1966. The primary goals of the contract research were to evaluate the accuracy of the energy budget and water budget and to determine the effectiveness of monolayer forming chemicals in reducing evaporation at Lake Hefner, using a stationary sprinkler application system. During the course of the study, it was decided that the value of the evaporation study would be greatly enhanced if a way could be found to correlate lake evaporation with evaporation from a large sunken tank or a pond. A thorough search of the literature indicated that, while at least three prominent investigators had postulated that evaporation from a sunken tank 12 or 15 feet in diameter would approach that from a nearby lake, a direct comparison had never been made (33), (45), (57). The literature review also revealed that apparently no one had ever made a direct comparison of the evaporation from a large lake and a nearby pond. The term "direct comparison with a nearby tank or pond" implies that all the bodies of water are contiguous and located in the same microclimatic area.

It was postulated that if the lake evaporation could be correlated with evaporation from a large sunken tank or pond by means of a prediction equation, this might eliminate the need for using the expensive and complicated energy budget method in future lake evaporation studies. Hopefully, it would also make possible the estimation of evaporation losses from lakes with an unreliable water budget.

Therefore, during the spring and summer of 1966 a group of sunken tanks and pans ranging in size up to 15 feet in diameter and 4 feet in depth were installed at the south instrument station at Lake Hefner. During the period of study, continuous records of daily evaporation, water surface temperatures, and relative humidity were maintained. A prediction equation was derived for lake evaporation as a function of the product of tank evaporation times the ratio of the vapor pressure deficits existing over the lake and the tank, respectively.

With the exception of the 15-foot tank, all tanks were installed in pairs and one tank of each pair was continuously treated with a monolayer forming chemical. The pairs of treated and untreated tanks and pans were used to determine the effects of water surface temperature, wind, and area of the evaporation surface upon the degree of evaporation suppression.

Evaporation data were also obtained from an instrumented pond 100 by 120 by 6 feet deep, located 65 miles northeast at Stillwater, Oklahoma. This pond had been the site of intensive evaporation studies in the past but had never been correlated with Lake Hefner before. The lake and pond are not in the same microclimatic area, but are located in areas having similar macroclimates, topography, and exposure.

This dissertation contains a considerable amount of additional material not included in the final report of the research project, which is entitled An Investigation to Evaluate Specific Techniques for Determining the Effectiveness of Monolayer Forming Materials in Reducing Evaporation Losses from Lake Hefner (8). It, along with theses by Fry (15), Mitchell (32), and Manges (29), is intended to compliment and supplement the final report.

CHAPTER II

OBJECTIVES

The three objectives set for this dissertation were:

1. To evaluate the accuracy of the energy budget method of estimating evaporation from Lake Hefner.
2. To investigate the effect of temperature, wind, and surface area of a body of water upon the evaporation reduction achieved by means of a monomolecular film.
3. To investigate the relationship between lake evaporation and evaporation from large sunken tanks and a pond.

CHAPTER III

REVIEW OF LITERATURE

Evaporation Studies

In the field of evaporation study scientific investigators have used four different methods to measure lake evaporation. These methods are:

1. Water budget method
2. Mass transfer method
3. Energy budget method
4. Pan to lake coefficient method

Water Budget Method

The water budget method of determining evaporation is a simple measuring of all incoming and outgoing water in order to determine the evaporation. The basic equation can be expressed as:

$$E = I - O - S \tag{1}$$

where

E = evaporation*

O = outflow

S = change in reservoir storage.

I = inflow

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*A complete list of symbols is given in Appendix G.

In 1950-51 Lake Hefner was the site of a large scale investigation of lake evaporation using the water budget and energy budget methods (49). Lake Hefner was originally chosen as a study lake after a survey of over 100 lakes and reservoirs in the West. It was chosen because of its near-circular shape, the prevailing south winds, and its accurate water budget. The water budget was exceptionally accurate because all inflows were metered, most runoff was diverted away from the lake, and all outflow was measured by the water plant.

In the 1950-51 Lake Hefner study Harbeck and Kennon (18) reported that daily evaporation results computed from the water budget were considered to have less than 5 percent error one-third of the time and less than 10 percent error three-fifths of the time. The total evaporation for the year of June 1, 1950, to May 31, 1951, was 53.75 inches.

Young (57) reported a satisfactory water budget study of evaporation at 5500 Lake Elsinore, California, for the years 1939-41. The average yearly evaporation for the three year period was 56.24 inches. The United States Geological Survey has recently completed an evaporation study at the 220,000 acre Salton Sea, using water budget and energy budget methods (20). The average yearly water budget evaporation for the years 1961-62 was 70.52 inches. Roberts (40) has used the water budget method to carry out evaporation suppression studies on two lakes of less than three acres in Illinois, and Crow (5) has used the water budget method to measure evaporation from two 0.28 acre ponds at Stillwater, Oklahoma.

Mass Transfer Method

In 1798 Dalton (11) described the driving force behind evaporation as the vapor pressure difference between the water surface and the air. Since that time many attempts have been made to derive a relationship correlating evaporation with wind speed and vapor pressure deficit. One of the earliest of modern-day workers in evaporation research was Rohwer (42), who conducted evaporation studies in Colorado in 1926-28 using an 85-foot diameter reservoir. His mass transfer equation is typical of many others:

$$E = (0.44 + 0.118\ W)(e_o'' - e_a'') \tag{2}$$

where

E = evaporation, inches

W = ground wind speed, mph

e_o'' = saturation vapor pressure at the water surface temperature, in inches of mercury

e_a'' = vapor pressure of the air, in inches of mercury

During the 1950-51 Lake Hefner study Marciano and Harbeck (30) derived the following semi-empirical equation for computing the lake evaporation using water budget data:

$$E = 6.25 \times 10^{-4}\ u_8\ (e_o - e_8) \tag{3}$$

where

E = evaporation, cm/3 hrs

u_8 = lake wind speed at 8-meter height, knots

e_8 = vapor pressure of the air at 8-meter height, mb

e_o = saturation vapor pressure of the air at the water surface temperature, mb.

Subsequent variations of this equation were used at Lake Hefner in 1958 (8), Sahuaro Lake in 1960 (47), Lake Cachuma in 1961 (51), Pactola Reservoir in 1962-63 (52), and Elephant Butte Reservoir in 1963-64 (53). The general form used to express the evaporation at all the locations above was:

$$E = n\, u\, (e_o - e_a) \tag{4}$$

where

E = evaporation, cm/day

n = mass transfer coefficient, cm/day mph mb

u = 2-meter lake wind speed, mph

e_o = saturation vapor pressure of the air at the water surface temperature, mb

e_a = vapor pressure of the air at 2-meter height, mb

An alternate method of expressing this relationship is as follows:

$$Q_e = N\, u\, (e_o - e_a) \tag{5}$$

where

Q_e = the energy used in evaporation, cal/cm^2 day

N = mass transfer coefficient, cal/cm^2 day mph mb

and

e_o, e_a, and u are as defined above.

Energy Budget Method

The computation of evaporation by the energy budget is based on the law of conservation of energy. The change in the stored energy of the lake must equal the difference between the incoming and the outgoing energy.

The energy budget method was first used by Schmidt (43) in 1915 to compute annual evaporation from the ocean. Angstrom (2) later used the energy budget method to compute evaporation from a lake. American investigation of the energy budget method received its first real impetus in 1926 when Bowen (4) developed the theory that the relationship between the energy used in evaporation and the energy going into sensible heat could be expressed as the ratio:

$$R = \frac{0.61\ P\ (T_o - T_a)}{1000\ (e_o - e_a)} \tag{6}$$

where

P = atmospheric pressure, mb

T_o = water surface temperature, °C

T_a = air temperature, °C

e_o and e_a are as defined above

Cummings and Richardson (10) demonstrated theoretically that the evaporation from a lake could be computed by using the energy budget and the Bowen Ratio.

The 1950-51 Lake Hefner study represented the first attempt to use the energy budget on a large lake. The energy budget there was expressed algebraically by Anderson (1) as:

$$Q_s + Q_a + Q_v - (Q_r + Q_{ar} + Q_{bs} + Q_e + Q_h + Q_w) = Q_o \tag{7}$$

If the Bowen ratio R is used to evaluate the energy Q_h conducted from the lake as sensible heat by $Q_h = RQ_e$ and by calculating the energy Q_w advected by the evaporated water by

$$Q_w = \frac{cQ_eT_e}{L}\ , \tag{8}$$

then the energy used in evaporation may be expressed as

$$Q_e = \frac{Q_s - Q_r + Q_a - Q_{ar} - Q_{bs} - Q_o - Q_v}{1 + R + cT_e/L} \tag{9}$$

where the terms are defined as:

Q_s = short-wave solar radiation incident to the water surface

Q_a = incoming long-wave atmospheric radiation

Q_v = net energy advected into the lake by inflow and withdrawal

Q_r = reflected solar radiation

Q_{ar} = reflected atmospheric radiation

Q_{bs} = long-wave radiation emitted by the body of water

Q_e = energy used by evaporation

Q_h = energy conducted by the body of water as sensible heat

Q_w = energy advected in the evaporated water

Q_o = change in energy stored in the body of water

R = Bowen ratio

c = specific heat of water, cal/gm °C

T_e = temperature of the evaporated water, °C

L = latent heat of vaporization, cal/gm

The theory outlined above was again used at Lake Hefner (48), Lake Meade (19), Lake Sahuaro (47), Pactola Reservoir (52), Elephant Butte Reservoir (53), and at the Salton Sea (20). During the first Lake Hefner study the application of the energy budget for periods greater than seven days resulted in a maximum accuracy approaching ± 5 percent of the mean water budget evaporation (1). However, the recently published Salton Sea report shows that the results of the energy budget can be as much as 60 percent low in the winter and 25 percent high in the summer (20). These seasonal errors tend to balance out over a period of a year, and the average annual energy budget evaporation (72.81 inches) at the Salton Sea was within 3 percent of the water budget evaporation (70.52 inches).

Hughes (20) concluded in the Salton Sea report that the major source of error in the energy budget was caused by inadequate measurement of the total incoming radiation by the ventilated flat plate radiometers. Hughes also believed that other errors resulted from ignoring the heat flux through the bottom of the reservoir. He estimated that ignoring this term could cause errors up to 3 percent in the summer and 20 percent in the winter. Other measurement errors were small in magnitude.

Recent Energy Budget Studies

One of the most widely used methods of estimating lake evaporation was an energy budget equation developed by Kohler, Nordenson and Fox (24) of the U.S. Weather Bureau, using data from the 1950-51 Lake Hefner study. The Weather Bureau equation was modified by Lamoreux (27) to the following form:

$$E_1 = [\exp ((T_a - 212)(0.1024 - 0.01066 \ln Q_s))$$

$$-0.0001 + 0.0105 (e_s - e_a'')^{0.88} (0.37 + 0.0041 u_p)]$$

$$X [0.015 + (T_a + 398.36)^{-2} (6.8554) 10^{10}$$

$$\exp (-7482.6/(T_a + 398.36))]^{-1} \tag{10}$$

where

E_l = lake evaporation, inches

T_a = air temperature, °F

e_a'' = vapor pressure of the air, inches of mercury

e_s = vapor pressure of the air at the dew point temperature, inches of mercury

Q_s = short-wave solar radiation incident to the water surface, cal/cm^2 day

u_p = pan wind movement at 24 inches above the ground, miles/day

One advantage of Equation 10 is that it is also available in graphical form for ease of computation (24). In this dissertation both forms will be collectively referred to as the "Weather Bureau Method". The Illinois Water Survey and the Texas Water Rights Commission, using historical data, have used the Weather Bureau Method to compute lake evaporation in those two states for every year since 1911 and 1906, respectively (41).

Kohler and Parmele (23) recently published the following evaporation prediction equation, which is essentially a modified version of an earlier equation by Penman (32):

$$E = \frac{(Q_{ir} - \varepsilon\sigma T_a{}^4) + E_a(\gamma + 4\varepsilon\sigma T_a{}^3/f(u))}{\Delta + (\gamma + 4\varepsilon\sigma T_a{}^3/f(u))} \qquad (11)$$

where

E = evaporation, in/day

E_a = (0.181 + 0.00236) $(e_s - e_a'')$

e_a'' = vapor pressure at 2-meter height, inches of mercury

e_s = as defined above

T_a = air temperature, °K

Δ = first derivative of e_o versus T_o, mb/°C

γ = psychrometric constant, mb/°C

Q_{ir} = difference between incident and reflected radiation (all wave)

σ = Stefann-Boltzmann Constant (7.8×10^{-11} equivalent inches of evaporation/cm^2 °K day)

ε = emissivity of the water surface

$f(u) = 0.0304\ u_4$

u_4 = lake wind speed at 4-meter height, miles/day

Preliminary tests of this equation, using historical data from five sites, indicate that it may provide reliable estimates of monthly and annual evaporation.

The Bowen Ratio

The energy budget equations discussed in this dissertation may contain inherent inaccuracies resulting from possible theoretical deficiencies of the equations. These equations are semi-empirical in nature either because of the inclusion of the Bowen ratio, or because they rely on the same assumptions as does the Bowen ratio. The Bowen ratio assumes that the transport mechanisms for heat and water vapor are essentially equal. The validity of the Bowen ratio has been debated for years, but at present it is considered valid for most atmospheric conditions. Pruitt (36,37) in a recent well-documented study has presented research results tending to support the validity of the Bowen ratio.

Pruitt used the following energy budget equation in his study:

$$R_n + G + L(ET) + H = 0 \tag{12}$$

where

R_n = net radiation, cal/cm^2 sec

G = soil heat flux, cal/cm^2 sec

H = convective heat flux, cal/cm^2 sec

ET = evapotranspiration, gms/cm^2 sec

The evapotranspiration (ET) and sensible heat (H) can be expressed as follows:

$$ET = \rho \; K_d \; dq/dz \tag{13}$$

$$H = \rho \; c_p \; K_h \; dt/dz \tag{14}$$

where

ρ = density of air, gms/cm^3

dq/dz = moisture gradient at 75 cm above the surface, 1/cm

dt/dz = temperature gradient at 75 cm above the surface, °C/cm

q = absolute humidity of the air, gms/gm

K_d = eddy diffusivity for water vapor, cm^2/sec

K_h = eddy conductivity for heat, cm^2/sec

z = height, cm

c_p = specific heat of air at constant pressure, cal/gm°C

Pruitt determined that the ratio of eddy diffusivity for water vapor over eddy conductivity for heat (K_d/K_h) was approximately 1.0 for unstable conditions. Under unstable conditions the air has a lapse rate greater than the dry adiabatic lapse rate, while under stable conditions the air has a lapse rate less than the dry adiabatic lapse rate. The actual value of K_h/K_d varied from 0.72 to 2.38 for 30-minute periods at 75 cm above the ground for tests run under highly unstable conditions, with most of the ratios in the range from 0.8 to 1.5. Thus, it appears that the ratio of K_h/K_d is approximately 1.0 under highly unstable conditions, and that the Bowen ratio is at least approximately correct. Pruitt found the Bowen ratio to be less reliable under highly stable conditions. However, highly stable conditions usually represent transfer of water from the atmosphere to the surface (dew).

Lake to Pan Method

Attempts have been made for many years to make use of lake to pan coefficients to predict lake evaporation. A summary of many of the early experiments is contained in the 1950-51 Lake Hefner report (49). In general, the yearly lake to pan coefficient is about 0.7, but this coefficient varies seasonally. Also, the lake to pan coefficient more nearly approaches unity as the pan is made larger and if the pan is sunken in the ground. (The term "pan evaporation", when used without qualifying remarks, refers to evaporation from a standard U.S. Weather Bureau Class A pan mounted on a wooden platform.)

In 1927, R. B. Sleigh (45) published the results of some evaporation studies with standard U.S. Weather Bureau Class A Pans and with sunken pans of various sizes up to 12 feet in diameter. He concluded that pan evaporation is inversely proportional to pan diameter and that beyond a pan diameter of 12 feet evaporation increases very little, if any. For example, the relative evaporation rates from sunken tanks 2.75 feet deep and 6, 9, and 12 feet in diameter were 108.9, 100.9, and 100 percent, respectively. Sleigh concluded that evaporation from the 12-foot tank would be about 101 percent of the evaporation from a lake, provided the wind, air temperature, and relative humidity were the same for both the lake and the tank. In Sleigh's study, the ratio of evaporation from the class A pan to the evaporation from the 12-foot tank averaged 1.5, but the ratio varied seasonally much as the pan to lake ratio varied for most lakes. Sleigh also conducted experiments with sunken pans ranging from 0.25 to 5.75 feet deep and concluded that an evaporation pan should be at least 2 reet deep but that little advantage was derived for depths greater than 3 feet. In view of Sleigh's findings, the absence from the literature of any direct comparison of evaporation from a 12-foot sunken tank with that from a nearby lake is somewhat surprising.

Young (57) compared the evaporation from a 12-foot sunken tank at Fullerton, California, with the evaporation from Lake Elsinore, California. The average yearly evaporation from the 12-foot tank was 53.53 inches per year (1936-1939, inclusive) versus 56.24 inches per year (1939-1941, inclusive) for the lake. However, the lake was about 35 miles away from the tank on the far side of a mountain range, and the elevation of the lake was about 1000 feet higher than the tank. Thus, the tank and the lake were not in the same microclimatic area.

Sleigh's research was partially confirmed by W. N. White (55) in Escalante Valley, Utah, in 1926-27. White found that the ratio of evaporation from a class A pan to the evaporation from a 12-foot sunken tank was 1.489 in 1926 and 1.495 in 1927. He also installed small sunken tanks 20 inches in diameter and 30 inches deep adjacent to the upwind and downwind sides of the 12-foot tank and found that the evaporation from the upwind tank greatly exceeded that from the downwind tank. Apparently, the 12-foot tank modified the moisture profile and/or the velocity profile of the air.

In 1955 Kohler, Nordenson, and Fox (24) published an equation for Class A pan evaporation based on data from eight widely scattered stations in the United States:

$$E_p = (e_s - e_a'')^{0.88} (0.37 + 0.0041\ u_p) \qquad (15)$$

where

E_p = pan evaporation, in/day

e_s = vapor pressure of the air at the dew point, inches of mercury

e_a'' = vapor pressure of the air, inches of mercury

u_p = pan wind movement at 24 inches above the ground, miles/day

This equation gave an excellent fit for data from pans at Lake Hefner. The predicted evaporation for the other seven stations was within 16 percent of the observed evaporation. An equation was also developed to predict lake evaporation from pan evaporation as follows:

$$E = 0.7\ (E_p + 0.00051\ P\ \alpha_p\ (0.37 + 0.0041\ u_p)(T - T_a) \qquad (16)$$

where

E = lake evaporation, in/day

T, T_a = pan water surface temperature and air temperature, °C

P = atmospheric pressure, mb

α_p = a function of P, u_p, and T representing the proportion of advected energy into the Class A pan utilized for evaporation

Equation 16 is similar to the Weather Bureau Method (Equation 10) discussed previously, except that the pan evaporation has been used as an indirect measure of solar radiation. The complexity of Equation 16 demonstrates the inadequacy of a simple lake to pan coefficient to predict lake evaporation unless these other variables are taken into consideration. Both Equations 10 and 16 were used by Meyer and Nordenson (31) to prepare evaporation maps for the seventeen western states.

In 1962 Nordenson and Baker (33) published the results of a four-year experiment with a 15-foot sunken tank. They found that the evaporation predicted by Equation 16 was within 2 percent of "lake evaporation" estimated from the 15-foot tank evaporation. The "lake evaporation" was computed by multiplying the 15-foot tank evaporation by a lake to tank ratio (not given) to correct for heat losses to the soil from the tank. They also found that the lake evaporation computed from Equation 10, using the input variables of air temperature, dewpoint temperature, solar radiation, and pan wind velocity, was within 1 percent of "lake evaporation" estimated from the 15-foot tank evaporation. The "lake evaporation" was estimated by multiplying the 15-foot tank evaporation by a lake to tank ratio of 1.05. In view of the importance and relevance of Equation 10, it was tested at Lake Hefner in 1965-66.

Evaporation Suppression Research

Shortly before 1900, Agnes Pockles (35) of Germany made the discovery that certain fatty alcohols would spread out in thin layers on the surface of water. Her researches were added to by Lord Rayledge (38), and later, by Rideal (39), who in 1925 proved that certain fatty alcohols could reduce evaporation by 50 percent or more. It remained for the Nobel Prize winner and eminent chemist, I. L. Langmuir (28), to conduct a thorough investigation into the properties of these materials, thereby proving that they spread out into monolayers one molecule thick, that they had a spreading pressure that could be measured with an apparatus, and that the evaporation of water through these monolayers was proportional to a decrease in pressure. Since that time numerous studies have been made of the effectiveness of hexadecanol (C_{16}) and octadecanol (C_{18}) films in reducing evaporation from evaporation pans (14).

In 1956 Crow (5,7) began a long-range series of evaporation suppression studies at Oklahoma State University, using a pair of rectangular lined ponds 0.28 acre in area. The evaporation reductions achieved by treating one pond with monomolecular films ranged up to 32 percent. The evaporation reduction was determined by a direct comparison of the evaporation rates from the treated and untreated ponds. Unfortunately, a simple direct comparison of evaporation rates cannot be used for determining evaporation reductions achieved on large lakes that have been treated with monomolecular films. Such a comparison would require two large lakes located near to each other, having similar shapes and exposures to prevailing winds, and having accurate water budgets. Such a pair of large similar lakes probably does not exist in the United States.

The lack of a simple direct comparison to determine evaporation reductions on large lakes has led to the development of two principal indirect methods. The combined energy budget and mass transfer method was introduced by Harbeck and Koberg (16) in 1959. Also, in 1958, the U.S. Bureau of Reclamation introduced the simplified method, developed by Florey, Garstka, and Timblin (12). The details of these methods are outlined in the following paragraphs.

Combined Method

This method is based on the combined use of energy budget and mass transfer theories, and depends on the fact that when a film is applied to a lake water surface, evaporation is reduced and the water surface temperature rises. The only energy budget terms assumed to be influenced by the temperature rise are Q_{bs}, Q_e, and Q_h (defined on Page 11). If the net effect of these terms is zero, a "change in outflow energy" budget may be written:

$$(Q'_{bs} - Q_{bs}) + (Q'_e - Q_e) + (Q'_h - Q_h) = 0 \tag{17}$$

where the symbols with primes refer to a lake with a film and those without primes refer to the same lake without a film. The terms Q'_{bs}, Q'_e, and Q'_h can be computed directly, but Q_{bs}, Q_e, and Q_h are all functions of the water surface temperature, T_o, which would have existed if no film had been applied.

Q_{bs} is calculated by the Stefan-Boltzman law using an emissivity coefficient of 0.97, thus

$$Q_{bs} = 0.97\ \sigma\ (T_o + 273.16)^4 \tag{18}$$

where

σ = Stefan-Boltzman constant for black-body radiation, 1.171×10^{-7} cal/cm^2 °K^4 day

T_o = water surface temperature, °C

The energy that would have been used in evaporation if a film had not been present is determined by the mass transfer equation previously discussed:

$$Q_e = N\, u\, (e_o - e_a) \tag{5}$$

The energy lost as sensible heat is calculated by a heat transfer equation similar to the above equation:

$$Q_h = K\, u\, (T_o - T_a) \tag{19}$$

where

K = heat transfer coefficient, cal/cm^2 day mph °C

The coefficients N and K, which are unique for each lake, must be determined during a pre-treatment evaluation that is representative of the treatment period.

Simplified Method

The simplified method involves the use of an empirical formula that is intended to account for the effect of a partial film cover on the lake and the variability of different chemicals in their ability to reduce evaporation. The estimated evaporation reduction, in percent, is proportional to the equation:

$$E_R = \frac{\Sigma\, C\, F\, u\, (e_o - e_a)}{\Sigma\, u\, (e_o - e_a)} \tag{20}$$

The lake film coverage factor, C is the ratio of actual film coverage to possible cover as determined by film cover maps. The evaporation reduction factor, F, is the percentage evaporation reduction obtained in concurrent tests on treated and untreated Class A evaporation pans. The lake wind speed, u, is measured at the 2-meter level. As originally used in the 1958 Lake Hefner investigation the quantities were computed for three-hour intervals, although other intervals can be used.

Since the original large-scale evaporation suppression investigation at Lake Hefner in 1958 the U.S. Bureau of Reclamation has conducted a number of large-scale tests using the simplified and combined methods to evaluate evaporation savings. A review of the results of these tests can be found in the 1965-66 Lake Hefner report (8).

Interrelationships Between Monomolecular Films and Water Temperatures

A reduction in evaporation caused by a monomolecular film will produce an increase in the water temperature. Crow (5) found that the temperature near the surface of a pond treated with a monolayer was 3.0°C higher than for an untreated pond. At a depth of 5 feet the difference was 1.7°C. Franzini (13) found a 4°C difference in water surface temperatures between a treated and an untreated evaporation pan. Jarvis (25) has demonstrated that for an untreated water surface exposed to a flow of dry nitrogen gas the water temperature was 4°C cooler than at a depth of 4 millimeters. When the same surface was treated with a stearic acid monolayer, the decrease was less than 1°C.

Several investigators have published linear regression equations relating the evaporation reduction factor, F, and the pan water surface temperature, T. A recent equation published by Runkles and Bartholic (52) is:

$$F = 112.0 - 0.59\ T \qquad (21)$$

$$R = -0.58 \qquad \text{Std. Dev.} = 5.39$$

where

F = evaporation reduction, percent

T = pan water surface temperature, °F

The temperature T used in the development of most published equations has been the average of the daily maximum and minimum pan temperatures, and not the actual average temperature.

Effects of Wind on Monomolecular Films

Numerous field studies have demonstrated the destructive effect of wind on monomolecular films. The U.S. Bureau of Reclamation (52) recently published data showing that the average coverage achieved on an 850-acre lake dropped sharply as wind speeds increased. Crow (6) found that when the wind speed was 10 miles per hour, a monomolecular film cover was blown off 80 percent of a water surface enclosed by barriers 3 inches high and 14.5 feet apart. The relationship between the evaporation reduction factor, F, and the wind speed was:

$$F = 37.7 - 3.88\ u$$

where

u = wind speed at 2-meter height, mph

The rate of film movement as a function of wind speed has been determined for several different locations under varying physical conditions. Mitchell (32) found at Lake Hefner in 1966 that the rate of advance of a monomolecular film on the lake was related to the wind speed as follows:

$$M = 0.037\ U_{ss-2}$$

where

M = film movement, mph

U_{ss-2} = 2-meter wind speed at the south instrument station, mph

CHAPTER IV

THEORY

The primary objective of this dissertation is to investigate the relationship between lake evaporation and evaporation from nearby sunken tanks or ponds. In this chapter certain boundary layer concepts will be examined to provide insight into this relationship.

Boundary Layer Conditions on a Flat Plate

Reynolds (21) has postulated that in turbulent fluid flow the eddy diffusivities for heat and momentum are equal at any point in the flow. Pruitt (36) and Yamamoto (56) have suggested that the same analogy exists between heat transfer and evaporation.

Consider the following example of thermal and velocity boundary layer development on the horizontal flat plate shown in Figure 1. The windward portion of the flat plate is unheated and the leeward portion is maintained at a constant temperature t_o. Except for a small area near the leading edge of the flat plate, the velocity boundary layer is turbulent. For the flat plate the velocity and temperature profiles can be expressed by the following equations (21):

$$U/U_\infty = (Y/\delta)^{1/7} \tag{22}$$

$$\frac{t_o - t}{t_o - t_\infty} = \frac{\Theta}{\Theta_\infty} = (Y/D)^{1/7} \tag{23}$$

where

t = air temperature

U_∞ = velocity of the air above the boundary layer

U = velocity of the air at an elevation Y

t_o = temperature of the leeward portion of the flat plate

t_∞ = air temperature above the boundary layer

Y = vertical distance from the surface of the flat plate

X = horizontal distance from the leading edge of the flat plate

$\delta(X)$ = thickness of the velocity boundary layer

$D(X)$ = thickness of the thermal boundary layer

$\delta_w(X)$ = thickness of the vapor concentration boundary layer

The thickness of the velocity boundary layer is given by the following equation:

$$\frac{\delta(X)}{X} = 0.37\ (U_\infty X/\nu)^{-0.2} \tag{24}$$

where

ν = kinematic viscosity

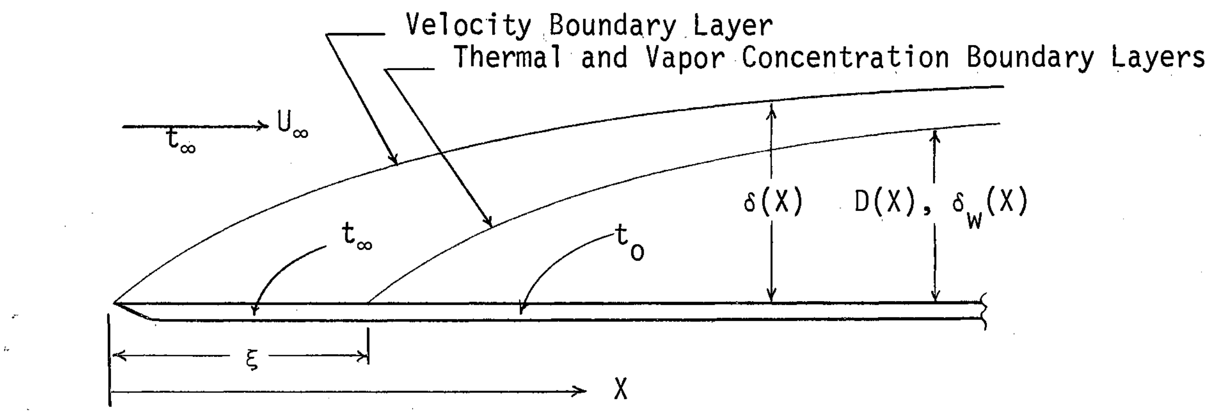

Figure 1. Thermal and Velocity Boundary Layer Development on a Partially Heated Flat Plate.

Kays (21) has shown that the local heat transfer from the flat plate is:

$$q''_x = \frac{\rho c_p U_\infty}{Pr^{0.4}} 0.0295 \ (U_\infty X/\nu)^{-0.2} \left[1 - (\xi/X)^{9/10}\right]^{-1/9} (t_o - t_\infty) \quad (25)$$

where

q''_x = local heat flux at the surface of the flat plate

Pr = Prandtl number (Pr = 0.7 for air)

ξ = length of the unheated portion of the flat plate

c_p = specific heat at constant pressure

Kays has also shown that Equation 25 may be approximated by:

$$q''_x = \frac{0.0295 \ \rho c_p U_\infty}{Re_x^{0.08} \ Re_\xi^{0.12} \ Pr^{0.4}} \quad (26)$$

where

Re_x = Reynolds number $(U_\infty X/\nu)$

Re_ξ = Reynolds number based on unheated length $(U_\infty \xi/\nu)$

Equation 26 shows that the local heat transfer flux is more dependent on the length of heated surface than on the length of unheated surface.

By analogy, the mass transfer boundary layer (also called vapor concentration boundary layer) (3) above a lake bordered by a non-evaporating upwind area can be assumed to be similar in form to the thermal boundary layer above the flat plate. Then, the local evaporation rate can be expressed as:

$$E_x = \frac{0.0295 \ U_\infty}{Pr^{0.4}} (U_\infty X/\nu)^{-0.2} \left[1 - (\xi/X)^{9/10}\right]^{-1/9} (c_o - c_a) \quad (27)$$

where

E_x = local evaporation rate, gm/cm^2 sec

c_o = vapor concentration at the water surface, gm/cm^3

c_a = vapor concentration above the boundary layer, gm/cm^3

Equations 25 and 27 can be integrated to yield solutions for the average heat flux and the average evaporation rate. They can also be modified to allow for upwind areas which have step increases in evaporation rates or surface temperatures.

Boundary Layer Conditions on a Lake Surface

Equations 25 and 27 could be used to compute the heat transfer and evaporation from a large lake if all the independent variables could be measured. Unfortunately, little is known about the evapotranspiration rates or the temperatures of the area upwind of Lake Hefner or of any other lakes, for that matter. The average yearly evaporation from the lake is about 54 inches and the average annual rainfall is 31 inches (49). Under the climatic and vegetative conditions prevailing at Oklahoma City the average amount of runoff would be about 4 inches, leaving about 27 inches average annual evapotranspiration from the area upwind from the lake (26). Therefore, the average upwind evapotranspiration at Lake Hefner is about 50 percent of lake evaporation. This figure is probably being modified by urban expansion into the lake area. The picture is further confused by diurnal and seasonal variations in evapotranspiration and temperatures. For example, the evapotranspiration from the vegetated area immediately after a heavy rain would be similar to the lake evaporation, but in the days following the rain they would become dissimilar.

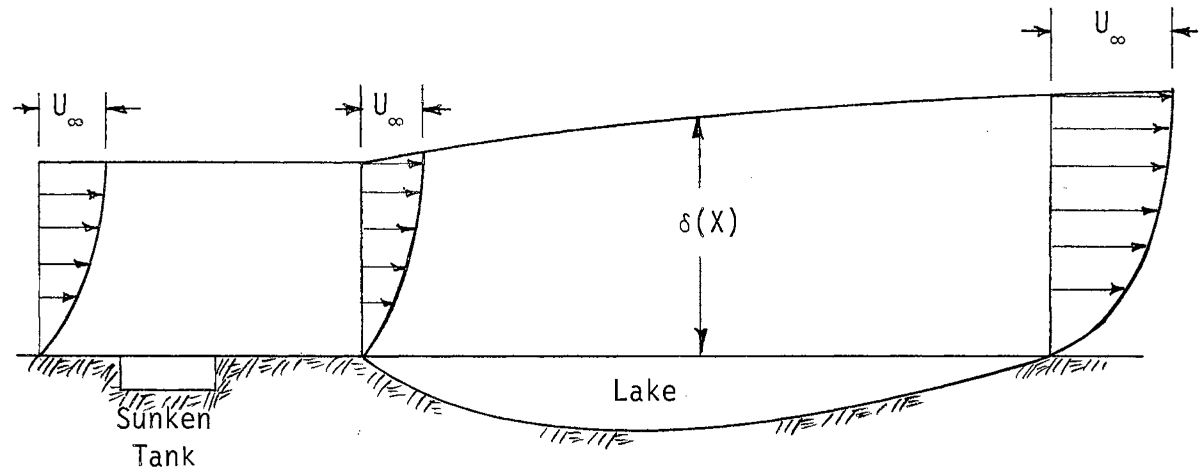

Figure 2. Velocity Boundary Layer Development Over the Lake.

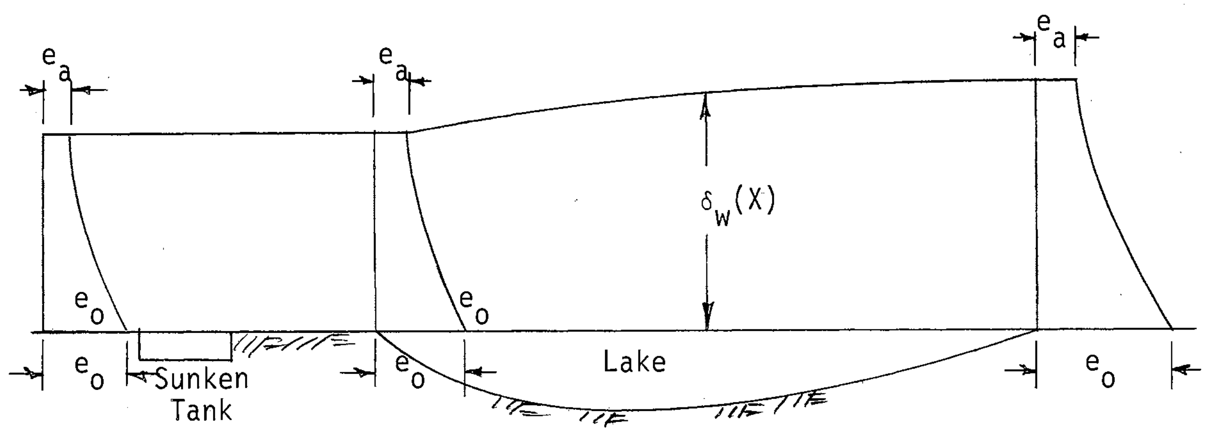

Figure 3. Vapor Composition Boundary Layer Development Over the Lake.

Figures 2 and 3 illustrate the theoretical boundary layer conditions which might exist at the lake and at a sunken tank near the lake if ξ is assumed to be very large. Fortunately, wind velocity profiles have been measured for considerable lengths of time at various locations around Lake Hefner. In 1966, Mitchell (32) found that the velocity profile on the windward (south) side of Lake Hefner could be expressed by:

$$U/U_0 = (Z/Z_0)^{0.203} \tag{28}$$

This equation is based on data taken at two and eight meters above ground level during the period of September 24 to October 14, 1966. The velocity profile on the leeward (north) side of the lake was expressed by:

$$U/U_0 = (Z/Z_0)^{0.169} \tag{29}$$

This equation is based on data taken at two and eight meters above the lake level during the period of September 24 to October 14, 1966. The wind velocities on the leeward side of the lake were greater at all elevations than those on the windward side.

Marciano and Harbeck (30) calculated that the thickness of the velocity boundary layer was as great as 47.4 meters by using an equation similar to Equation 24 and assuming that the boundary layer began to develop at the windward edge of Lake Hefner. However, it would seem that the conventional definition of boundary layer thickness as defined in Equation 24 is not valid here. As is indicated in Figures 2 and 3, the boundary layers do not begin at the edge of the lake, but merely become thicker over the lake. Mitchell's observations indicated that the thickness of the velocity boundary layer at the windward edge of the lake was always greater than 25 meters. Undoubtedly, the velocity boundary layer is somewhat greater over the lake than over the land. Since little is known about the vapor concentration boundary layer over the land, about all that can be suggested is that the vapor concentration boundary layer should be thicker over the lake than over the land.

Development of a Mathematical Model for Lake Evaporation

The evaporation from Lake Hefner could be expressed by a modified version of Equation 27. If the thicknesses of the vapor concentration profiles over the land and the lake are reasonably similar, the term ξ/X can be dropped from Equation 27 leaving the following:

$$E_x = \frac{0.0295\ U_\infty}{Pr^{0.4}} (U_\infty/\nu)^{-0.2} (X)^{-0.2} (c_o - c_a) \tag{30}$$

Then, if we assume X to be a large constant unknown number, and convert the vapor pressure deficit term to more familiar units, Equation 30 could be modified to:

$$E = C_1\ U_\infty(U_\infty/\nu)^{-0.2} (e_o - e_a) \tag{31}$$

where

C_1 = a coefficient

E = average lake evaporation, cm/day

e_o and e_a are as previously defined

By assuming X to be constant, we eliminated the need to integrate Equation 31 to determine the average evaporation rate. If the -0.2 exponent is disregarded and the 2-meter lake wind speed is substituted for U_∞, this equation reverts back to Equation 4:

$$E = n\ u\ (e_o - e_a) \tag{4}$$

The evaporation from the sunken tank adjacent to the lake can be expressed by:

$$E_t = n_1\ u_{2m-ss}\ (e_o' - e_a) \tag{32}$$

where

E_t = evaporation from sunken tank, cm/day

E = average lake evaporation, cm/day

n_1 = mass transfer coefficient for the sunken tank, cm/day mph mb

u_{2m-ss} = wind velocity at the 2-meter height at a shore station near the sunken tank, mph

e_o' = saturation vapor pressure at the water surface temperature of the sunken tank, mb

Then the ratio of lake evaporation to tank evaporation can be expressed:

$$\frac{E}{E_t} = \frac{n\ u\ (e_o' - e_a)}{n_1 u_{2m-ss}\ (e_o' - e_a)} \tag{33}$$

Analysis of Mitchell's data for 1965 and 1966 (8,32) indicated that for 26 periods of approximately one week each, the wind speed ratio u/u_{2m-ss} varied from 1.33 to 1.82, with an average value of 1.50. The variations were random in nature and did not appear to be correlated with the magnitude of the wind speed. Substitution of the wind speed ratio into Equation 34 leads to the following:

$$\frac{E}{E_t} = \frac{1.50\ n\ (e_o - e_a)}{n_1\ (e_o' - e_a)} = C_2\ \frac{(e_o - e_a)}{(e_o' - e_a)} \tag{34}$$

where

C_2 = a coefficient

This can be expressed:

$$E = C_2\ \frac{(e_o - e_a)_L}{(e_o' - e_a)_t}\ E_t \tag{35}$$

Thus, if a large sunken tank is located adjacent to a lake, the lake evaporation is determined by the product of the tank evaporation times the constant C_2 and the ratio of the vapor pressure deficits.

In the 1950-51 Lake Hefner study, Kohler (49) plotted the ratio of lake evaporation to Class A pan evaporation versus the ratio of the vapor pressure deficits for the lake and pan and determined the following:

$$\frac{E}{E_p} = \frac{0.7\ (e_o - e_a)}{(e_o' - e_a)} \tag{36}$$

where

E/E_p = ratio of Lake Hefner evaporation to Class A pan evaporation

e_o' = saturation vapor pressure at the pan water surface temperature, mb

This can be expressed:

$$E = \frac{0.7\ (e_o - e_a)}{(e_o' - e_a)} \quad E_p \tag{37}$$

The plot of Kohler's data showed some scatter, probably because of the large variations in pan water surface temperatures and because of disturbance of the wind profile caused by the sides of the pan. Webb (54) used some of Kohler's data to derive a modified form of Equation 37. The results predicted by Webb's equation were also somewhat scattered, but he concluded that the equation would predict monthly total lake evaporation with a standard error of less than 10 percent.

CHAPTER V

EXPERIMENTAL PROCEDURE AND INSTRUMENTATION

General

During the course of the evaporation study at Lake Hefner the following parameters were measured:

1. Solar radiation and total incoming radiation
2. Water surface elevation
3. Precipitation
4. Rate, duration, and temperature of inflow and outflow
5. Water surface temperatures of the lake and of the evaporation pans and tanks
6. Lake temperature profile
7. Relative humidity and air temperature
8. Wind speed
9. Evaporation from pans, tanks, and pond

The locations of the instrument stations at Lake Hefner are shown on Figure 4. The principal instrument station was the south station, located on a short peninsula at the south side of the lake. This station is at the same site used in 1950-51 and 1958. In the spring of 1965, a wind vane, anemometers, lithium chloride (LiCl) hygrometers, evaporation pans, a recording rain gage, an Eppley pyrheliometer, a Beckman and Whitley flat plate radiometer, and a CRI were installed as shown in Figures 5 and 6. An air-conditioned trailer at the site housed

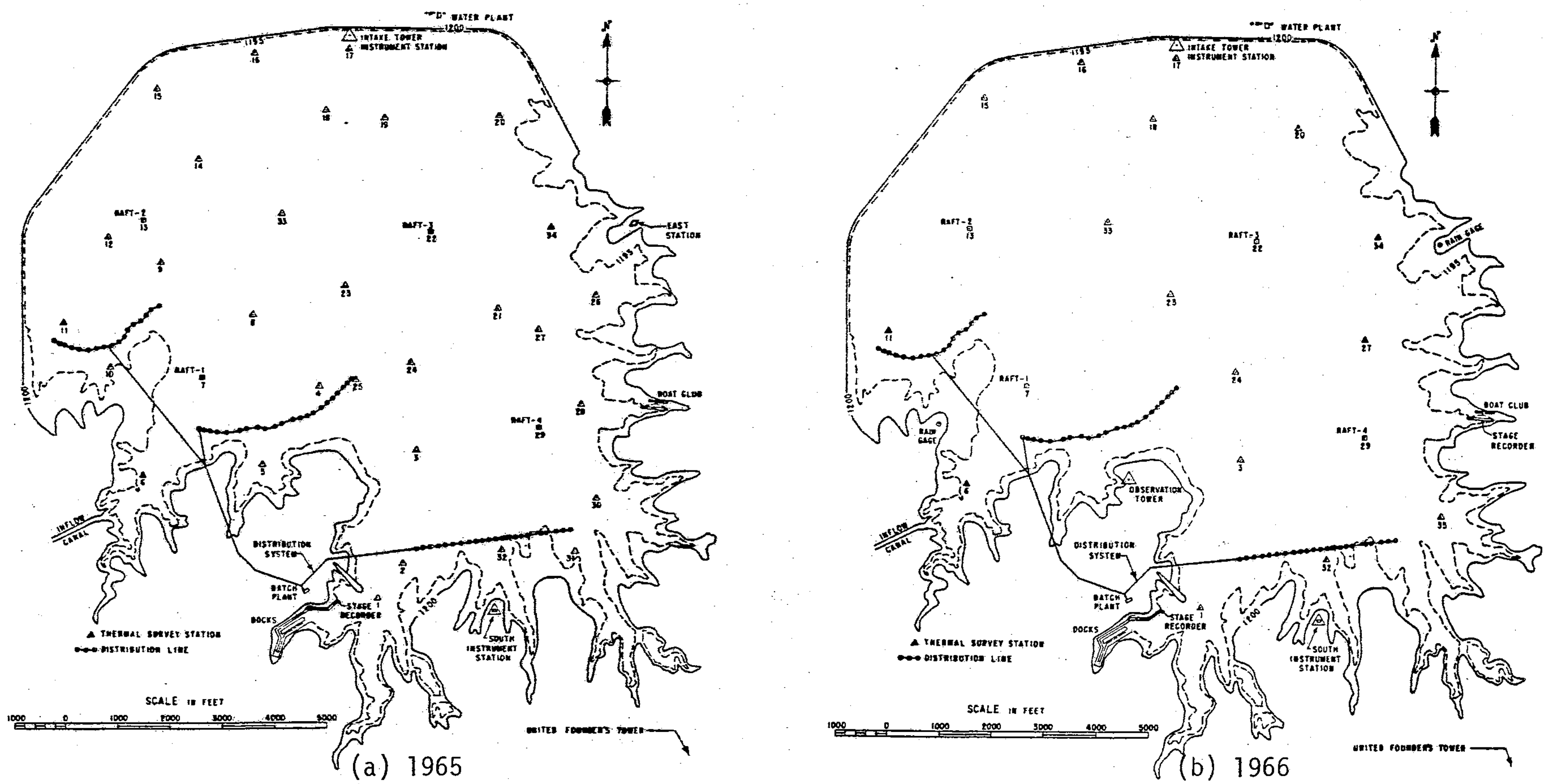

Figure 4. Maps of Lake Hefner Showing the Instrumentation Stations, the Location of the Thermal Survey Points, and the Distribution System for the 1965 and 1966 Investigations.

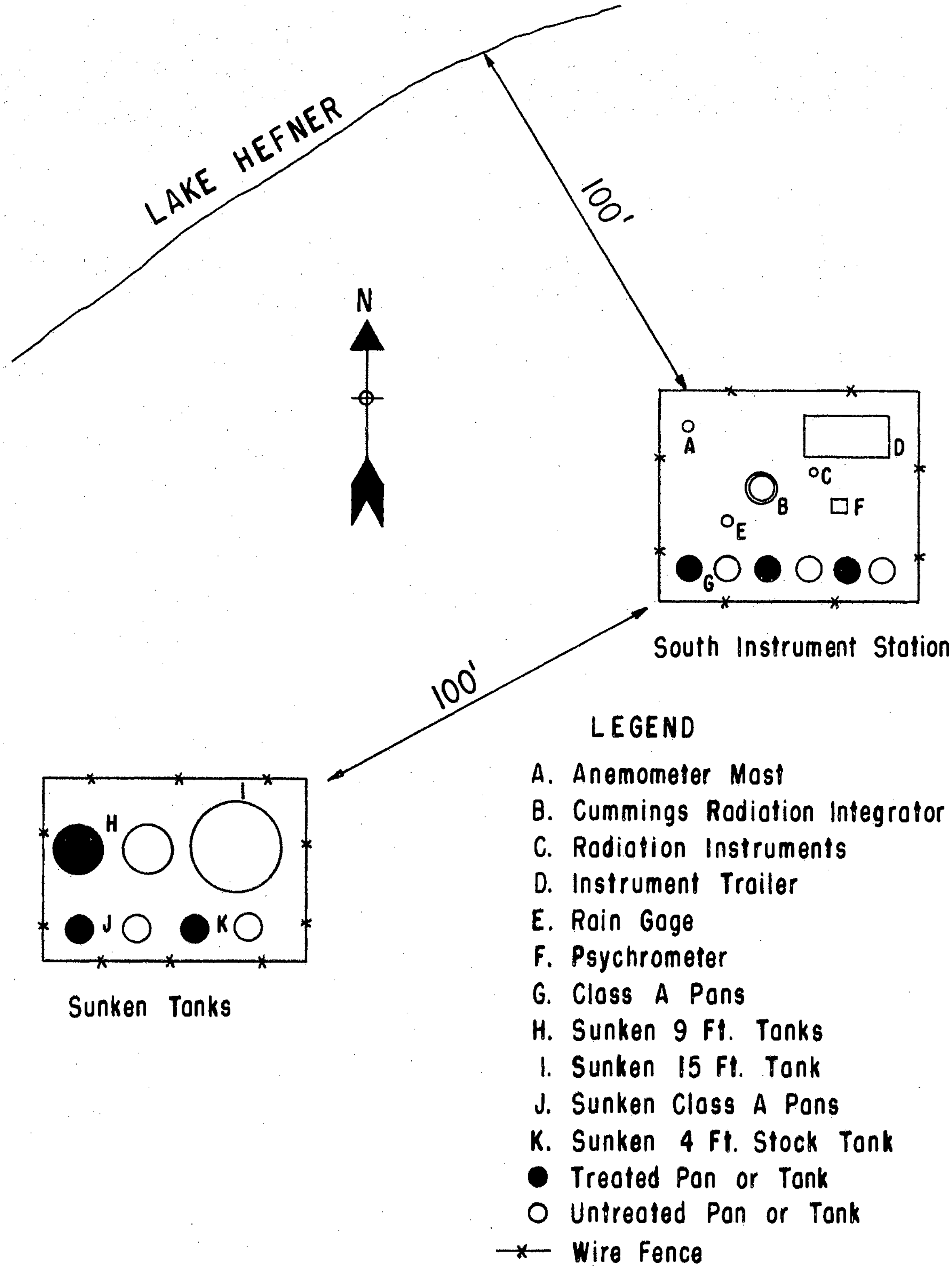

Figure 5. Plan View of the South Instrument Station and the Sunken Tanks.

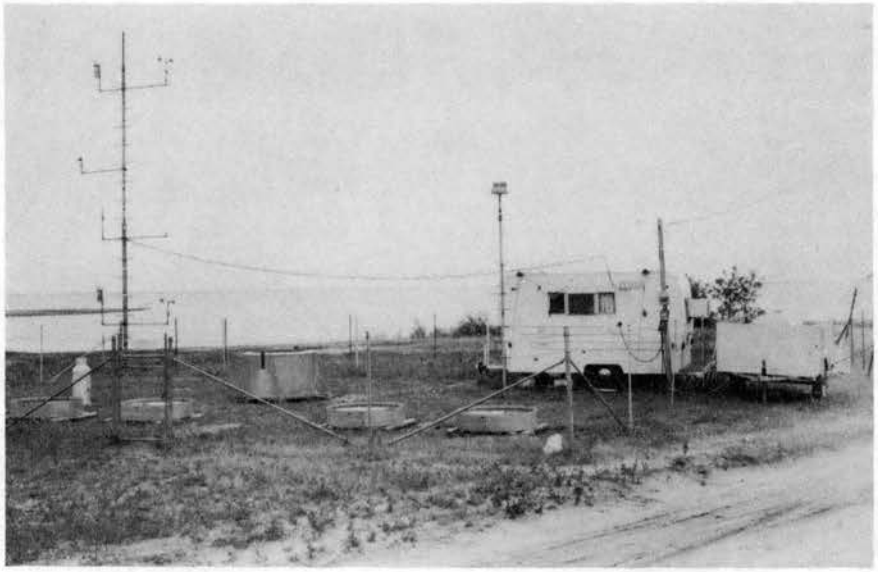

Figure 6. South Station Instrument Site.

Figure 7. Intake Tower Instrument Site.

the recording equipment. In 1966, a group of sunken tanks, shown in Figure 5, were installed at a location 100 feet southwest of the south station.

Another set of meteorological instruments was installed at the intake tower located in the north side of the lake about 75 feet out from the dam (Figure 7). The records from the intake tower station, other than the rainfall record, were used only to fill in periods of missing data at the south station.

At the east station, located on the east shore of the lake, a recording rain gage was maintained during 1965 and 1966. A partially instrumented Cummings Radiation Integrator (CRI) was maintained at this station in 1965.

In order to provide a continuous record of reliable data, every instrument around the lake was visited daily on a regular servicing schedule. During the daily visit to the instruments normal maintenance and servicing were performed and the calibration of the recorders was frequently checked. After September 15 of each year the servicing of the instruments was less frequent because the start of the university semester necessitated the moving of the operating personnel to Stillwater.

Solar Radiation and Total Incoming Radiation

The incoming short-wave radiation, Q_s, was measured by an Eppley 180-degree 50-junction pyrheliometer. The instrument, shown in Figure 8, was mounted on top of a 13-foot mast at the south station. The glass bulb of the Eppley pyrheliometer was wiped with a soft cloth once a week to remove dust. The output from the Eppley pyrheliometer

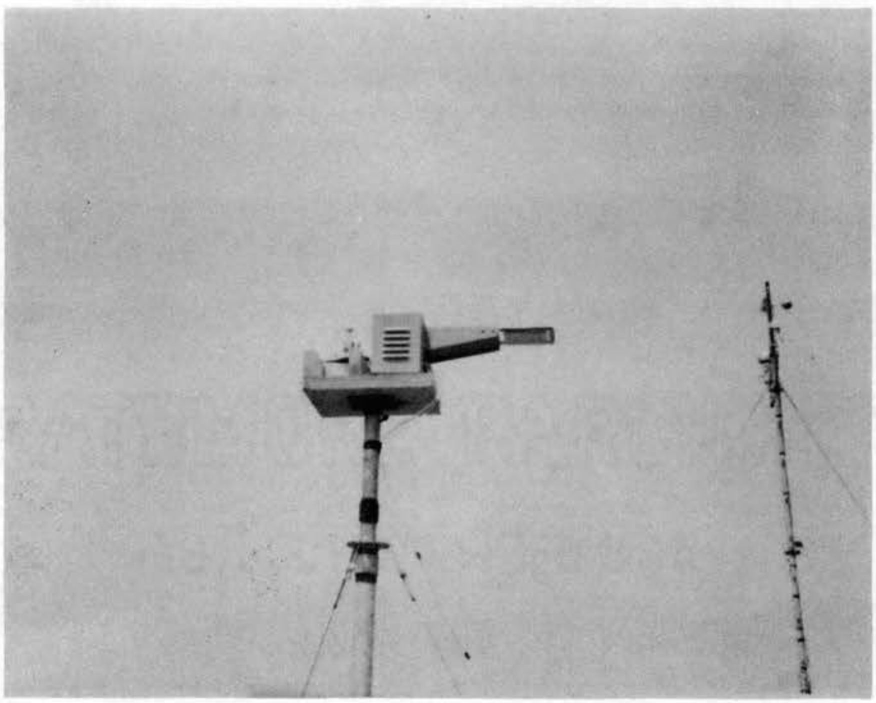

Figure 8. Eppley Pyrheliometer and Beckman-Whitley Flat Plate Radiometer Located at South Station.

was modified by a voltage divider and then recorded by a Honeywell Universal Electronik recorder directly in calories/cm^2min. A portion of the recorder chart is shown in Figure 9.

The total incoming radiation, $Q_a + Q_s$, was measured by a Beckman and Whitley ventilated thermal radiometer, mounted on the same mast with the Eppley pyrheliometer. This instrument is commonly called a flat plate radiometer. The output from the flat plate radiometer was modified by a voltage divider and recorded on the same chart as the Eppley output.

The wide scatter of the radiation data on cloudy days made interpretation of the data very difficult. In an effort to make scaling of the radiation data easier in 1966, a Moseley dual pen recorder, which recorded continuous traces of the output from the Eppley and flat plate radiometer, was used.

The computation of $Q_a + Q_s$ requires both the flat plate voltage output and the flat plate back radiation, the latter of which is calculated from the flat plate temperature. The flat plate temperature was measured by a thermocouple in the flat plate and the output was recorded on a Honeywell multipoint recorder. The surface of the flat plate radiometer was washed about once a week to remove dust.

In order to provide a check on the total incoming radiation, a Cummings radiation integrator (CRI) was operated at the south station during the 1965 and 1966 seasons. The CRI is essentially an insulated evaporation tank, in which evaporation losses provide a measure of the net incoming radiation. The results of data from the CRI provided only a rough check on the net incoming radiation and therefore are not discussed in detail in this dissertation.

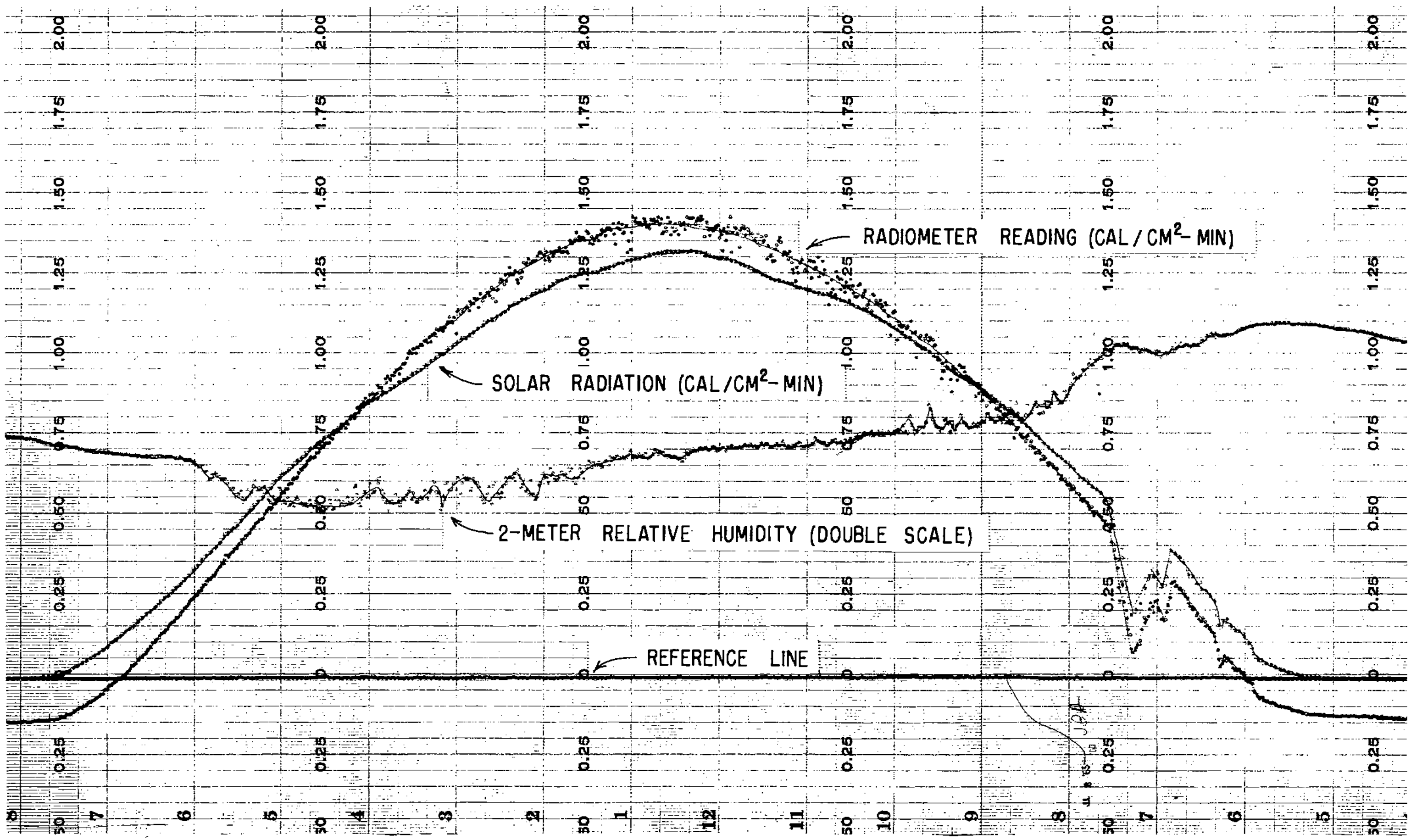

Figure 9. Minneapolis-Honeywell Recorder Traces of Output from Radiation and Relative Humidity Sensing Instruments at South Station.

Water Surface Elevation

In 1965 the lake stage was recorded by two Stevens Type A-35 stage recorders. The south lake gage was located on a boat dock in the small boat harbor about 50 feet from shore. A short line of levels was run from United States Geological Survey datum to this gage and it was set to the sea-level datum. Although the small boat harbor was protected by a breakwater, a continuous appreciable seiche with a period of approximately 15 minutes was observed at the boat dock gage.

The north lake stage recorder was installed on the intake tower on June 25, 1965. The gage was set to mean sea-level datum by adjusting the trace to agree with the boat dock recorder on an exceptionally calm day, July 16, 1965.

An examination of the 1965 stage records indicated that an additional stage recorder would have been desirable to improve stage records on extremely windy days when the wind tended to create a differential between the north and south sides of the lake. Therefore, before the start of the 1966 season, a third stage recorder was installed at the sailboat club docks on the east side of the lake. The trace was set to a common datum as in 1965. The stage recorder at the sailboat club docks was in a sheltered position and gave a relatively smooth trace.

Precipitation

During 1965 standard recording rain gages were maintained at the south station and the east station. A nonrecording rain gage was installed on top of the intake tower at an elevation of 30 feet above the water surface. Records from these three gages were used in the 1965 energy budget computations. A standard nonrecording rain gage was operated at the Lake Hefner water treatment plant by the Oklahoma City Water Department. The records from the gage were used to supplement the records of the other three rain gages for the 1965 water budget computations.

An examination of the rainfall records for 1965 indicated the need for an additional rain gage on the west side of the lake. In 1966, a recording rain gage was installed on the western side of the lake and the four rain gages operated by project personnel were used exclusively for the 1966 evaporation computations.

Lake Inflow and Outflow

The only measured inflow into the lake was through the inflow canal, located at the southwest corner of the lake. The inflow was measured at the United States Geological Survey (USGS) gaging station shown in Figure 10. The gaging station consisted of a steel weir for low flows, a concrete weir for high flows, and a Stevens A-35 recorder. An additional stage recorder farther down the canal occasionally was used to measure high flows. All inflow records were computed by the USGS office in Oklahoma City.

The temperature of the inflowing water was measured by a mercury-in-steel pressure type probe and recorded on a Honeywell circular chart temperature recorder. The instrument was checked daily with a mercury-in-glass thermometer.

A record of the water treatment plant withdrawals was provided by Oklahoma City Water Department personnel. The withdrawals were

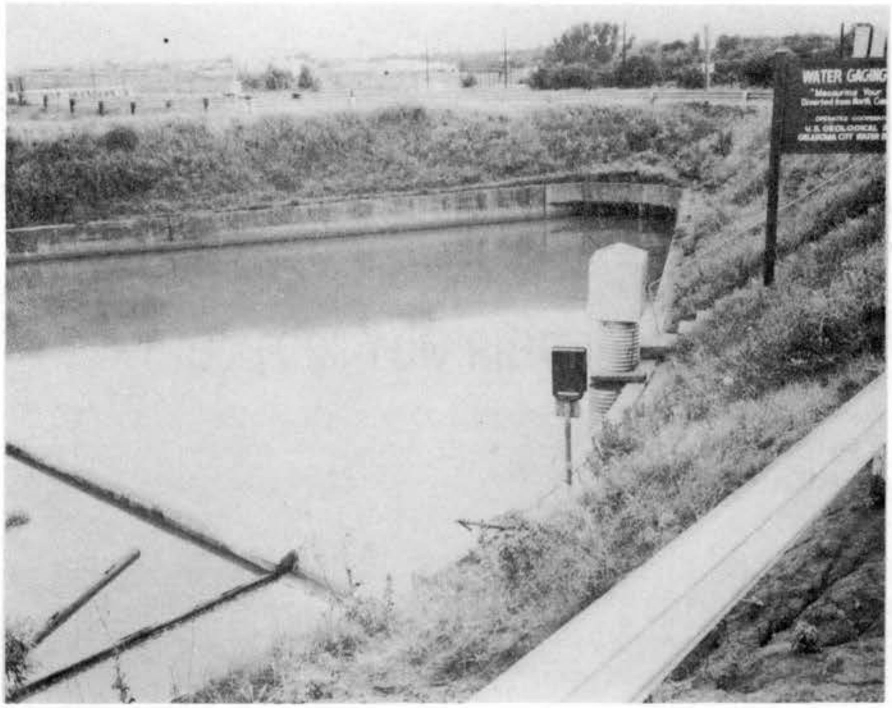

Figure 10. U.S. Geological Survey Gaging Station on the Lake Hefner Supply Canal.

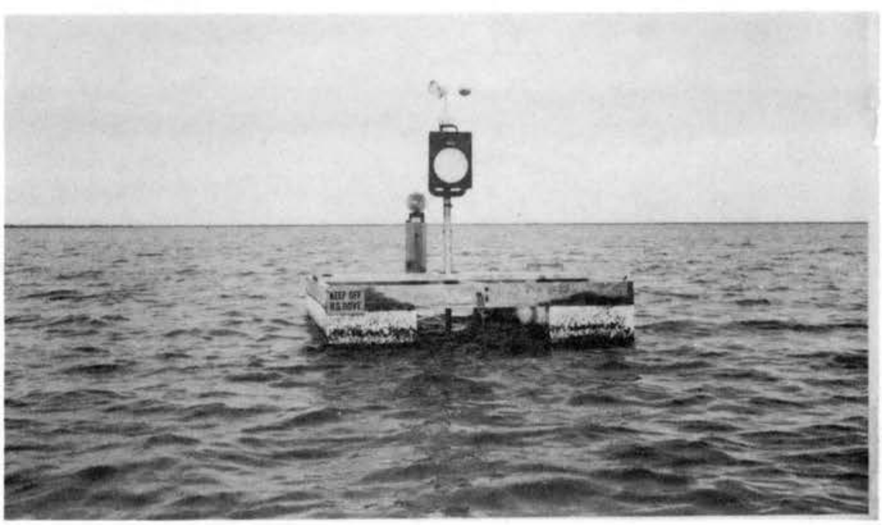

Figure 11. Typical Instrument Raft Measuring Wind Travel and Water Surface Temperature.

measured by a venturi meter, estimated to be accurate within ± 3 percent of the true discharge rate. The temperature of the water was determined from a sample taken each morning at 0830.

Lake Water Surface Temperature

The lake water surface temperatures were registered by recorders mounted on four rafts. The locations of the rafts are shown in Figure 4, and a typical raft and recorder are illustrated in Figure 11. The recorders were of the same type as the one at the inflow station. The mercury-in-steel probe was set at one-half inch below the lake surface. During very windy weather the rough waves on the lake caused the probe to alternately submerge and emerge from the water and also caused the pen to scribe a very wide trace. However, calibration checks of the recorder indicated that the recorded temperatures were accurate within 0.5°C. After October 15, 1966, the lake surface temperature was measured by a single recorder at the intake tower.

Lake Temperature Profile

The stored energy, Q_0, of the lake at any desired point in time was determined by making a thermal survey that consisted of temperature profiles at selected locations. Temperatures were measured at 0, 2.5, 5, 7.5, and every 5 feet thereafter until the bottom was reached. In 1965, thirty-one stations, each marked by a buoy, were located as shown on Figure 1a. In 1966, this number was reduced to the nineteen shown on Figure 1b in order to shorten the time required to make a thermal survey.

The temperature profile measurements were made with a Whitney Underwater Thermometer. The temperature sensing device was a thermister bead housed in a weighted shield at the end of an electrical cable. The output from the thermister was read from an indicating microammeter and recorded manually. The instrument was calibrated at the beginning of each season and calibration curves were established. The small correction indicated by the calibration curves was applied by a computer program when the stored energy of the lake was calculated. Frequent spot checks of the calibration of the instrument were made during each thermal survey.

In making energy budget computations, the interval between thermal surveys is referred to as a thermal survey period (TSP). During 1965 and 1966, twenty-six and forty-two thermal surveys were made, respectively. Many more thermal surveys than TSPs were made in order to end the TSP at a favorable time if unfavorable weather (rain) occurred.

Relative Humidity and Air Temperature

In 1965, relative humidity and air temperature were measured at the south station by means of lithium chloride (LiCl) hygrometers and thermocouples located at 1, 2, 4, and 8 meters above the ground. In 1966, the relative humidity and air temperatures were recorded only at 2 and 8 meters.

One of the original reasons for installing the LiCl hygrometers at several elevations was to measure the vapor composition profile of the air. However, the inaccuracy of the instruments for this purpose soon became apparent, and only the data from the 2-meter level was processed. The calibration of the LiCl hygrometers was checked daily against a battery-powered psychrometer. On numerous occasions the relative humidities indicated by the LiCl hygrometers were in error by 5 percent or more, especially after rains had occurred. The LiCl sensing elements in the hygrometers apparently experienced a calibration shift after prolonged periods of 100 percent humidity.

On July 6, 1966, a thermocouple psychrometer was installed at the south station. Relative humidity records from this instrument were used exclusively after July 17, 1966. In contrast to the LiCl hygrometers, this instrument gave satisfactory results and was nearly always in very close agreement with the battery powered psychrometers.

Relative humidity and air temperature were measured at the intake tower in 1965 and 1966 by means of LiCl hygrometers and thermocouples. Originally, it had been planned to compare the vapor composition profile at the intake tower with that at the south station in order to evaluate the changes made by the passage of the air over the lake. Unfortunately, the accuracy of the measurements did not warrant processing the data from the intake tower for this purpose. The errors in measurement of the relative humidity were probably of the same order of magnitude as the differences between the two stations.

Wind Speed

In 1965, totalizing anemometers were installed at 1, 2, 4, and 8 meters above the ground at the south station and 2, 4, and 8 meters above the lake level at the intake tower. In 1966, the anemometers were located only at the 2- and 8-meter levels at each station. During both years totalizing anemometers were located at the 2-meter level on the four rafts, as shown in Figure 7. Wind direction was measured by a wind vane located 8 meters above the ground at the south station.

During 1965, a complete record of wind speed at the 2- and 4-meter levels at the south station was recorded on two channels of a 10-channel Esterline Angus event recorder. The other 8 channels were used to record wind direction. All anemometer odometers were read daily in order to provide a check on the Esterline Angus recorder and to furnish a record for those anemometers not connected to the recorder. During the 1966 season the 2- and 8-meter wind speeds were recorded by the Esterline Angus recorder. In 1966, anemometers were also installed at 2, 4, 8 or 16, and 25 meters above the ground on a steel observation tower located on the south side of the lake (Figure 4).

Raft wind passage was recorded by a solenoid pipping device, which punched a hole in the circular temperature chart for each 10 miles of wind travel. The odometers on the raft were read during the daily raft check. The pipping mechanisms were not used in 1966, as it was discovered that the hourly values of lake wind speed could be estimated from a relationship between daily wind travel at the 8-meter south station anemometer and the raft anemometers.

Evaporation Pans, Tanks, and Pond

In 1965, six Class A evaporation pans were installed at the south station, as shown in Figures 5 and 12. During the period of June 3 to August 5, 1965, all six pans were maintained under identical conditions. From August 6 to September 9, 1965, two pans were maintained; from September 10 to October 23, 1965, three pans were treated daily with one gram of the evaporation-suppressing alcohol and three were untreated. Pan temperature records for the Class A pans were not maintained in 1965.

Figure 12. Class A Evaporation Pans at South Station.

In 1966, records for the six Class A pans were maintained from June 11 until December 4. Beginning June 23, 1966, 5 or more grams of evaporation-suppressing alcohol were added to three of the pans every other day. On August 16, 1966, a pair of the Class A pans were set in the ground as shown in Figure 13 and treatment was continued on one of the pair until December 4.

In addition to the evaporation pans, two 9-foot diameter stock tanks, two 4-foot diameter stock tanks, and a 15-foot diameter swimming pool, also referred to as a 15-foot tank, were set in the ground with about 2 inches of their rims projecting above the ground, as shown in Figures 13, 14, and 15. The water level in the sunken tanks was maintained at approximately ground level, but the water level in the swimming pool was maintained about 2 to 4 inches below ground level in order to prevent any loss of water from high waves. The sunken stock tanks were made of galvanized steel and were 24 inches deep. All the galvanized tanks were checked for leaks by filling them with water before installation. It was necessary to caulk all seams with an epoxy cement to prevent leakage. The swimming pool was made of a vinyl liner supported around the cylindrical surface by a sheet metal frame. The depth of the swimming pool varied from 48 inches around the edge to approximately 60 inches at the center of the pool.

Each tank was provided with a stilling well similar to a Class A pan stilling well and the daily evaporation was determined from hook gage readings. The stages were read at about 0900 each day until September 19, and thereafter they were read at 1600 on the days when a daily check was made. The time of reading was somewhat out of phase

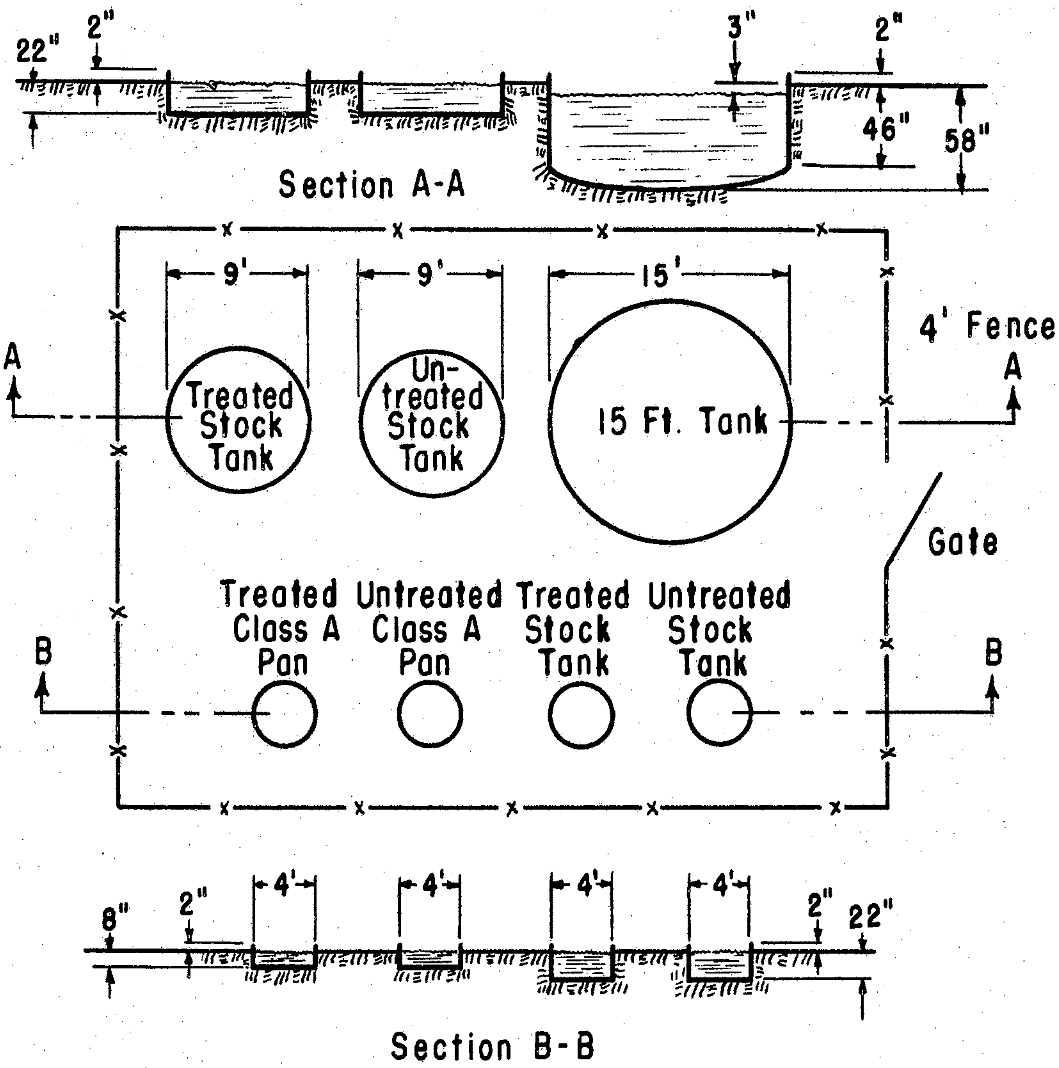

Figure 13. Sunken Tanks and Pans at the South Station.

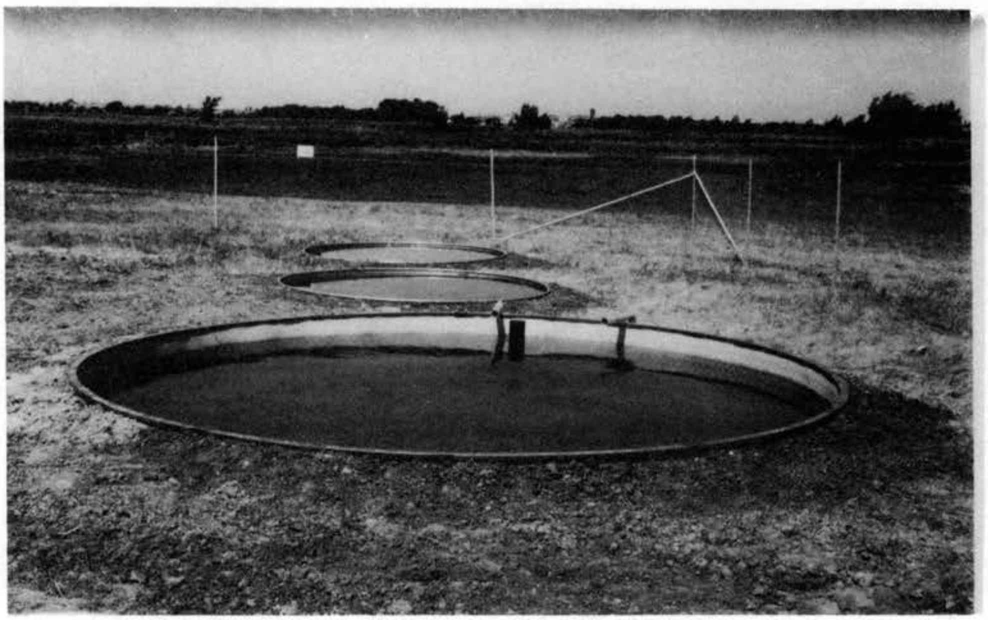

Figure 14. Large Sunken Tanks at the South Station. The 15-foot tank is in the foreground and the two 9-foot tanks are in the background.

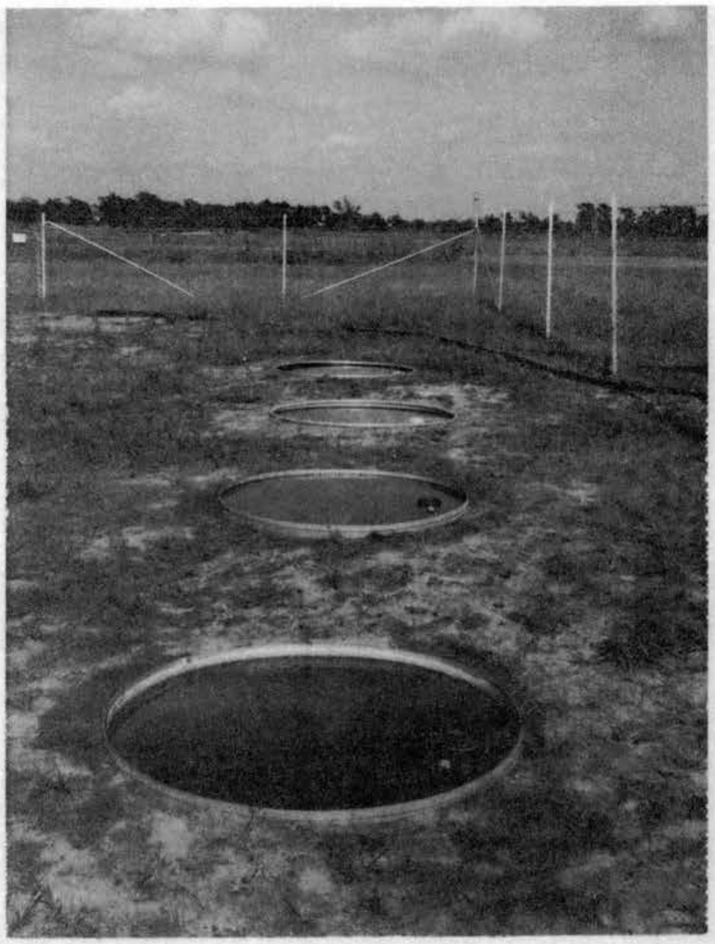

Figure 15. Small Sunken Tanks and Pans at the South Station. The sunken Class A pans are in the foreground and the sunken 4-foot tanks in the background.

with the lake water budget, which had been set up on a 2400-2400 basis, but this phase shift was of negligible importance when the lake evaporation and tank evaporation were compared on a weekly basis.

The surface water temperatures of all tanks and pans, except two of the Class A pans, were recorded during most of the 1966 season. The temperatures were measured by floating thermocouples of the type shown in Figure 12. The output of the thermocouples was recorded on two Honeywell multipoint recorders and a Leeds and Northrup Speedomax recorder. One of the recorders converted the thermocouple output directly to °F, but the other recorders required an ice-bath reference junction. A small amount of data was lost at various times because of ice melting in the ice bath.

A continuous record of the treated Class A pan water surface temperature was maintained from June 23 to December 4, 1966. Records for the untreated Class A pan, the 9-foot tanks, and 15-foot tank were maintained from mid July to December 4, 1966, and records for the sunken 4-foot diameter tanks were kept from August 16 to December 4, 1966.

The evaporation pond used in this study is located on the crest of a windswept hill at the northwest edge of the city of Stillwater, Oklahoma. It is one of a pair of identical ponds of dimensions 100 by 120 by 6 feet. The pond was lined with a plastic vinyl liner. Numerous checks have shown that leakage from the pond is negligible. The daily evaporation from the pond was obtained from a simple water budget that contained only the items of pond stage, rainfall, and evaporation. The rainfall was measured by a standard rain gage located at the pond. The runoff area draining into the pond was small relative to the size of the pond, and runoff was ignored. The refilling of the pond to a suitable level after each prolonged period of evaporation was done in a few hours and the missing evaporation record was estimated. The pond evaporation measurements were made by H. L. Manges (29) for use in his doctoral dissertation. Through his cooperation, a complete record of pond evaporation was obtained for the periods of July 25 to October 26, 1965, and July 25 to November 8, 1966.

Lake Evaporation Suppression Tests

A complete description of the chemical distribution system and the lake evaporation suppression tests is given in the 1965-66 Lake Hefner report (8). However, because of the important effect of the evaporation suppression tests on the data in this thesis, a brief description of the equipment and tests is given.

The chemical distribution system consisted of two pumps of 50 and 150 gpm capacity, a pipeline to the batching plant where the chemical was mixed into a slurry with water, and three distribution lines with irrigation sprinklers located as shown in Figure 4. The distribution lines were located near the south side of the lake in order to take advantage of the prevailing southerly winds.

During treatment periods hourly maps of film coverage were made by means of a plane table. In 1965, the plane table mapping station was located at United Founders Tower, 2.9 miles southeast of the center of the lake and 219 feet above the average lake level. In 1966, the plane table was located in a steel observation tower 92 feet above the mean level. The location of the tower is shown in Figure 4.

CHAPTER VI

DISCUSSION OF WATER BUDGET PARAMETERS

Thermal Survey Periods

The basic accounting period for all evaporation calculations was the Thermal Survey Period (TSP). Table I shows the beginning and ending dates of TSP's. Several days with high rainfall rates or high inflow rates were not included in any TSP. The periods August 5 to 9, 1965, August 2 and 3, 1966, and September 3 and 4, 1966, were excluded because of high rainfall. September 16 to 24, 1965, was excluded because of high inflow rates associated with refilling of the lake. Those TSP's during which the lake was treated with a monomolecular film are indicated in Table I by an asterisk.

Discussion of Individual Terms in the Water Budget

All relevant water budget terms for 1965 and 1966 are summarized by TSP in Table II. The daily values of all water budget terms are shown in Appendix A.

Lake Stage

The stage-area-capacity data used in the 1965-66 Lake Hefner study are shown in Table III. These were developed from a detailed topographic map provided by the Oklahoma City Water Department. The

TABLE I

THERMAL SURVEY PERIOD DATES AND TIME INTERVALS FOR THE 1965-66 LAKE HEFNER INVESTIGATION

TSP	BEGINNING Date	BEGINNING Time	ENDING Date	ENDING Time	TIME INTERVAL Hours	TIME INTERVAL Days
1965						
1	June 3	1230	June 10	0800	163.5	6.812
2	June 10	0800	June 17	0800	168.0	7.000
3	June 17	0800	June 24	0800	168.0	7.000
4	June 24	0800	July 1	0830	168.5	7.021
5	July 1	0830	July 8	0830	168.0	7.000
6	July 8	0830	July 15	0830	168.0	7.000
7	July 15	0830	July 22	0830	168.0	7.000
8	July 22	0830	July 29	0800	167.5	6.979
9	July 29	0800	Aug 5	0830	168.5	7.021
10	Aug 9	1030	Aug 16	1000	167.5	6.979
11	Aug 16	1000	Aug 23	0700	165.0	6.875
12	Aug 23	0700	Aug 31	0700	192.0	8.000
13	Sept 1	0800	Sept 6	0730	119.5	4.979
14	Sept 6	0730	Sept 10	0700	95.5	3.979*
15	Sept 10	0700	Sept 16	1200	149.0	6.208
16	Sept 24	1300	Oct 2	0900	188.0	7.833
17	Oct 2	0900	Oct 10	0730	190.5	7.938
18	Oct 10	0730	Oct 23	0900	313.5	13.062
1966						
1	June 14	0815	June 21	0730	167.2	6.969
2	June 21	0730	June 28	0800	168.5	7.021
3	June 28	0800	July 6	1030	194.5	8.104
4	July 6	1030	July 12	0800	141.5	5.896*
5	July 12	0800	July 25	1000	314.0	13.083
6	July 25	1000	Aug 2	1230	194.5	8.104*
7	Aug 3	0930	Aug 10	1130	170.0	7.083*
8	Aug 12	0930	Aug 19	1400	172.5	7.188*
9	Aug 19	1400	Aug 28	0800	210.0	8.750
10	Aug 28	0800	Sept 3	1700	153.0	6.375*
11	Sept 4	1730	Sept 12	1700	191.5	7.979*
12	Sept 12	1700	Sept 21	1600	215.0	8.958
13	Sept 21	1600	Sept 29	1530	191.5	7.979**
14	Sept 29	1530	Oct 6	1500	167.5	6.979
15	Oct 6	1500	Oct 15	1130	212.5	8.854
16	Oct 15	1600	Oct 22	1600	168.0	7.000
17	Oct 22	1600	Oct 29	1600	168.0	7.000
18	Oct 29	1600	Nov 5	1600	168.0	7.000
19	Nov 5	1600	Nov 12	1600	168.0	7.000
20	Nov 12	1600	Nov 19	1600	168.0	7.000
21	Nov 19	1600	Nov 27	1600	192.0	8.000
22	Nov 27	1600	Dec 4	1600	168.0	7.000

* Treated TSP

** Partially Treated TSP

TABLE II

WATER BUDGET EVAPORATION SUMMARY FOR LAKE HEFNER, 1965-66

TSP	Stage Chg feet	Plant With feet	Irrig With feet	Seepage feet	Inflow feet	Rain feet	Thermal Exp feet	Evaporation feet	Evaporation inches	Evaporation cm
1965										
1	0.0230	0.1678	0.0041	0.0033	0.2581	0.0115	0.0050	0.0764	0.9168	2.3287
2	1.9620	0.1093	0.0042	0.0042	1.9180	0.1417	0.0050	-0.0150	-0.1800	-0.4572
3	3.3370	0.1164	0.0042	0.0033	3.5928	0.1138	0.0044	0.2501	3.0012	7.6230
4	1.6070	0.1252	0.0042	0.0041	1.8499	0.0854	0.0071	0.2019	2.4228	6.1539
5	-0.2290	0.1669	0.0042	0.0033	0.0469	0.0479	0.0050	0.1544	1.8528	4.7061
6	-0.3480	0.1799	0.0042	0.0034	0.0033	0.0008	0.0003	0.1649	1.9788	5.0262
7	-0.4100	0.2113	0.0042	0.0027	0.0008	0.0000	-0.0006	0.1920	2.3040	5.8522
8	-0.1770	0.1516	0.0042	0.0030	0.0010	0.1379	0.0015	0.1586	1.9032	4.8341
9	-0.2500	0.0538	0.0042	0.0035	0.0010	0.0000	-0.0061	0.1834	2.2008	5.5900
10	-0.1900	0.0621	0.0041	0.0063	0.0028	0.0169	-0.0035	0.1337	1.6044	4.0752
11	-0.1610	0.0619	0.0043	0.0054	0.0011	0.0246	0.0049	0.1200	1.4400	3.6576
12	-0.2300	0.0786	0.0038	0.0064	0.0013	0.0306	-0.0043	0.1688	2.0256	5.1450
13	-0.0850	0.0059	0.0010	0.0054	0.0008	0.0373	-0.0014	0.1094	1.3128	3.3345
14	-0.0620	0.0000	0.0027	0.0032	0.0007	0.0000	0.0049	0.0617	0.7404	1.8806
15	-0.2370	0.0360	0.0043	0.0045	0.0005	0.0031	-0.0164	0.1794	2.1528	5.4681
16	-0.2070	0.0000	0.0019	0.0077	0.0043	0.0040	-0.0130	0.1927	2.3124	5.8735
17	-0.0920	0.0000	0.0020	0.0090	0.0011	0.0004	-0.0047	0.0778	0.9336	2.3713
18	-0.1540	0.0000	0.0016	0.0158	0.0025	0.0787	-0.0088	0.2090	2.5080	6.3703
TOTALS	4.0970	1.5267	0.0634	0.0945	7.6869	0.7346	-0.0207	2.6192	31.4304	79.8332
1966										
1	-0.0744	0.1680	0.0026	0.0042	0.0073	0.2125	0.0003	0.1197	1.4360	3.6476
2	-0.3981	0.2298	0.0054	0.0072	0.0014	0.0000	0.0077	0.1647	1.9759	5.0187
3	-0.4648	0.3085	0.0077	0.0075	0.0013	0.0000	0.0103	0.1527	1.8321	4.6534
4	-0.4025	0.2477	0.0066	0.0031	0.0011	0.0000	0.0058	0.1519	1.8228	4.6299
5	4.6129	0.3934	0.0095	0.0045	5.4438	0.0896	0.0037	0.5167	6.2010	15.7505
6	-0.2362	0.2202	0.0039	0.0030	0.0881	0.0479	0.0059	0.1510	1.8117	4.6018
7	-0.4025	0.2571	0.0039	0.0024	0.0027	0.0162	-0.0018	0.1562	1.8742	4.7604
8	-0.1651	0.2423	0.0029	0.0067	0.0023	0.1885	0.0015	0.1056	1.2677	3.2200
9	-0.0099	0.1189	0.0013	0.0111	0.2210	0.0854	-0.0196	0.1653	1.9836	5.0383
10	-0.0875	0.0825	0.0013	0.0067	0.0019	0.0642	0.0067	0.0697	0.8368	2.1255
11	-0.2198	0.1050	0.0009	0.0080	0.0028	0.0000	-0.0059	0.1028	1.2332	3.1324
12	0.5807	0.1157	0.0003	0.0105	0.6207	0.1929	0.0138	0.1203	1.4431	3.6655
13	-0.1958	0.1620	0.0024	0.0090	0.0065	0.0923	-0.0044	0.1167	1.4005	3.5573
14	-0.3314	0.1317	0.0019	0.0083	0.0019	0.0008	-0.0199	0.1723	2.0675	5.2515
15	-0.3489	0.1918	0.0040	0.0106	0.0029	0.0000	-0.0058	0.1395	1.6743	4.2528
16	-0.2734	0.1261	0.0009	0.0078	0.0025	0.0308	-0.0127	0.1593	1.9111	4.8542
17	-0.2275	0.1482	0.0028	0.0063	0.0022	0.0000	-0.0023	0.0700	0.8401	2.1339
18	-0.2537	0.1333	0.0020	0.0060	0.0014	0.0000	-0.0062	0.1076	1.2912	3.2797
19	-0.2034	0.1372	0.0016	0.0072	0.0016	0.0073	-0.0037	0.0627	0.7519	1.9099
20	-0.2111	0.1454	0.0019	0.0076	0.0008	0.0000	0.0008	0.0578	0.6938	1.7624
21	-0.1728	0.1576	0.0017	0.0076	0.0566	0.0242	0.0022	0.0889	1.0669	2.7100
22	-0.2592	0.1218	0.0009	0.0092	0.0007	0.0017	-0.0127	0.1170	1.4038	3.5656
TOTALS	2.558	0.9441	0.0667	0.1547	0.4715	1.0544	-0.0363	3.0683	36.8192	93.5212

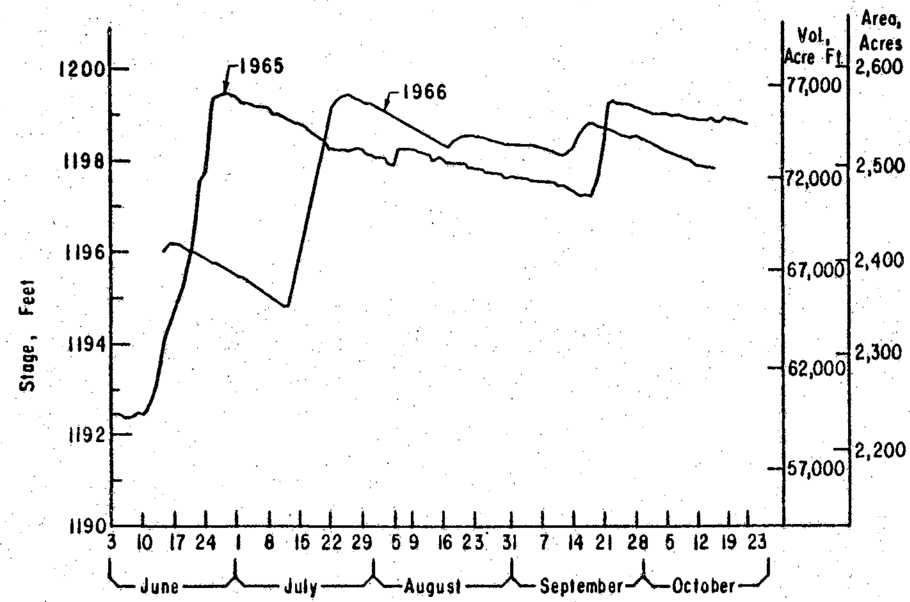

Figure 16. Variation of Lake Stage, Area and Volume During 1965 and 1966.

TABLE III

STAGE-AREA-CAPACITY DATA USED IN 1965-66 LAKE HEFNER INVESTIGATION

Stage Ft	Area Acres	Volume Acre Feet
1110	0	0
1115	6.97	16.29
1120	30.53	103.10
1125	58.75	322.48
1130	90.28	692.25
1135	193.17	1384.76
1140	258.22	2509.31
1145	353.14	4031.53
1150	477.27	6099.78
1155	604.06	8796.89
1160	773.66	12232.46
1165	956.87	16550.68
1170	1162.31	21840.31
1175	1372.07	28169.01
1180	1607.39	35609.90
1185	1862.95	44277.90
1190	2119.51	54227.15
1195	2358.81	65417.62
1200	2596.10	77800.11

variations of stage, area, and volume of the lake during the study periods are shown in Figure 16.

Lake stages were scaled from the recorders for the beginning and ending time of each thermal survey period and at 2400 of each day until October 15, 1966. After that date, all lake stages were scaled at 1600 each day. A continuous appreciable seiche with a period of about 15 minutes was recorded at the boat dock which necessitated averaging lake stages over several oscillations to obtain the final value. It was estimated that the maximum amount of error due to this method of averaging would be 0.0066 foot (2 millimeters) or less. This error would be insignificant over the thermal survey period, but could be appreciable when calculating evaporation on a daily basis.

Extremely high winds occurring during storms caused a massing of the water on one side of the lake with one recorder giving a higher and one recorder giving a lower reading than the average lake elevation. Differences in the order of 0.0165 foot often occurred. During ordinary winds of 10 to 15 miles per hour the recorders were usually within 0.0033 to 0.0066 foot of each other. The magnitude of this difference is appreciable if compared to the average daily evaporation. However, it is only 2 to 4 percent of the evaporation for a week long thermal survey period.

Precipitation

Rainfall on the lake surface was frequently a major item in the Lake Hefner water budget and energy budget computations. Rainfall was higher than normal for much of the 1965 season. As shown in Table IV the monthly rainfall amounts varied considerably between stations. The variation between stations for short individual storms was even more marked, indicating a need for more gages. In 1966 a better distribution of gages resulted when the west station gage was substituted for the water plant gage. In the 1950-51 Lake Hefner Investigation 22 rain gages were used and the standard error for each storm was computed. Such a statistical analysis of the 1965 and 1966 rainfall was not made. However, an examination of the lake stage recorder charts indicates that for some of the days on which rainfall occurred, the stage changes during the rain were different from the depth of rain recorded by the rain gages even when normal evaporation and other inflows and outflows were taken into consideration. On the few days when this occurred, it was possible to adjust the rainfall data by means of the lake stage records.

TABLE IV

COMPARISON OF MONTHLY TOTAL RAINFALL BY STATION

Month	South Station in	East Station in	Intake Tower in	Water Plant in	West* Station in	Average in
1965**						
June	3.81	5.00	3.67	4.43	---	4.22
July	2.52	2.31	1.94	2.29	---	2.26
Aug	5.28	5.88	6.40	4.35	---	5.48
Sept	6.47	6.76	6.70	3.01	---	6.99
Oct	1.11	0.99	0.77	0.91	---	0.95
Total	19.19	20.94	19.48	19.99	---	19.90
1966***						
June	2.55	2.55	2.55	---	2.55	2.55
July	1.88	1.59	1.41	---	1.72	1.65
Aug	4.18	4.20	4.02	---	4.22	4.16
Sept	3.54	3.39	3.98	---	3.21	3.53
Oct	0.00	0.00	0.00	---	0.00	0.00
Total	12.15	11.73	11.96	---	11.70	11.89

* West Station substituted for Water Plant in 1966
** From June 3 to October 23, 1965 only
*** From June 14 to October 15, 1966 only

Surface Inflow

Virtually all inflow into Lake Hefner was through the inflow canal at the southwest side of the lake. Surface inflow data were obtained from the Oklahoma City office of the U.S. Geological Survey. The weighted average flow rates in cubic feet per second for each day were calculated by that office. These rates were converted to volume and divided by the lake surface area at 2400 of each day to obtain the daily stage change due to inflow.

There were two major inflows during 1965 and one during 1966 when the lake was filled almost to spillway level by releasing water from Canton Reservoir. High rates of inflow occurred from June 10 to June 28, 1965. All or part of TSP's 2, 3, and 4 were included in this period. The maximum flow rate of 1150 cfs occurred on June 23 and caused a daily stage change of 0.9188 foot. Another inflow occurred on September 21 to 23 with a maximum flow rate of 871 cfs and daily stage change of 0.6748 foot. This period was not included in any TSP. The 1966 release was made during TSP 5 between July 13 and July 25 with the maximum daily stage change of 0.6086 foot occurring on July 22.

A small negative evaporation was indicated for part of the time during the high inflow of June, 1965, which was measured at the lower gage. The inflow during September, 1965, was measured at the upper gage and also resulted in negative evaporation on September 21 and 22, when the total calculated inflows for those days were 0.4876 and 0.6748 foot, respectively. There can be no doubt that these errors were caused by errors in inflow measurements. Since considerable errors exist in the inflow data the water budget data during any period of high inflow is subject to question. Therefore these periods were eliminated from consideration when such critical comparisons as the lake/pond and lake/tank evaporation ratios were being determined.

Fortunately the method of operating the lake was to fill the lake only once or twice during a summer. The inflow between times of maximum release was quite small and probably was due largely to leakage at the gates to the inverted siphon which supplies water to the canal. The inflow was typically 0.5 to 22 cfs, resulting in stage changes of 0.0004 to 0.0170 foot per day.

Runoff

The amount of local inflow due to surface runoff was believed to be quite small and no attempt was made to account for it. Diversion drainage ditches have been constructed around virtually all of the southern half of the lake to prevent runoff water from the highly developed urban areas from reaching the lake. The drainage area inside the diversion ditch is about 1000 acres, or about 40 percent of the lake area in size. Except for roads, the surface was covered with good native grass or bermuda grass. It is unlikely that any significant amount of runoff occurred from rains of one inch or less. Any attempt to assign runoff amounts to larger rains might possibly result in significant errors.

Water Plant Withdrawals

Withdrawal by the water plant was the third largest quantity in the water budget equation. Only surface inflow and evaporation caused a greater change in stage. The maximum daily withdrawal was 38.2 million gallons on July 18, 1966, which caused a stage change of 0.048 foot. The average daily withdrawal was considerably less. In both 1965 and

1966 water plant withdrawals were greater in the early part of the season. Except for TSP 15 there were no withdrawals from Lake Hefner after TSP 14 in 1965. Water plant usage was much higher in 1966 than 1965. Stage change by withdrawals was 126 percent of stage change by evaporation in 1966 compared with 60 percent in 1965. Considering possible effects of measurement error if the water plant venturi meter was accurate within 3 percent, as assumed, the error in computed evaporation could have been less than 4 percent in 1966 and less than 2 percent in 1965.

Seepage

Shallow seepage losses were measured by the Oklahoma City Water Department at six small weirs below the dam. The total stage change due to these losses amounted to 3.6 percent of evaporation stage change in 1965 and 4.3 percent in 1966. There was no way to check the accuracy of the seepage measurements, but since they amounted to a very small part of the total stage change errors in seepage measurement would have had little effect on the accuracy of the water budget evaporation.

Irrigation

Two 18-hole golf courses were irrigated from the lake using four pumps with a combined capacity of 1250 gallons per minute. Irrigation was scheduled by automatic timers and a fairly uniform program was followed. Cumulative pump operating timers were installed on August 20, 1965. The estimated irrigation withdrawals for the period prior to that date were based on the average for August 21 to 31, 1965, because the amount of irrigation decreased sharply after September 1, 1965. The total withdrawal for irrigation was the smallest item in the water budget and amounted to only slightly over 2 percent of evaporation for both seasons. Therefore, possible errors in estimating this term had no significant effect on evaporation computations.

Thermal Expansion

Thermal expansion was calculated for each TSP to eliminate errors due to change in water density. The lake surface area, volume and weighted average temperature from the thermal survey data were used in the computations, which followed the procedures outlined in the 1950 Lake Hefner Report. The effect of thermal expansion was about the same magnitude as for seepage (but not always the same algebraic sign). The lake cooled rapidly in September of both seasons, resulting in a maximum thermal expansion of -0.016 foot in TSP 15 of 1965 and -0.0199 foot in TSP 14 of 1966. The estimated error in the thermal expansion adjustment is assumed to be zero.

CHAPTER VII

DISCUSSION OF ENERGY BUDGET PARAMETERS

Data Processing

The bulk of the 1965 data recorded on strip charts was reduced using an Amsler integrator. The theory and procedure for using this instrument have been well documented and will not be repeated here. Detailed analysis of procedures for the 1965 investigation may be found in a thesis by Fry (15). The charts containing the millivolt output corresponding to the solar radiation, total radiation, relative humidity, and temperatures were integrated over intervals of 60 hours. This was the maximum possible chart length that the Amsler integrator could handle for chart speeds of one inch per hour. With this procedure average values for each TSP could be calculated, but average daily values were not available. In 1966 it was desired to tabulate part of the data on a daily basis, as in the case of the water surface temperature, relative humidity, and vapor pressure. Because of the utility of the digital computer in making repeated calculations and printing out the results, the University's IBM 7040 computer was used almost exclusively in processing of the 1966 data. This change in procedure made it possible to show the 1966 results in considerably more detail than for 1965.

The frequency of sampling of data for the 1966 data processing is shown in Table V.

TABLE V

FREQUENCY OF SAMPLING PARAMETERS FOR 1966 DATA PROCESSING

Parameter	Sampling Interval
Eppley pyrheliometer reading	6 min
Flat plate radiometer reading	6 min
Flate plate radiometer temperature	6 min
Dry bulb air temperature	30 min
Wet bulb air temperature	30 min
Relative humidity	30 min
CRI surface temperature	30 min
Lake surface temperature	1 hr
Lake inflow temperature	1 hr
Wind speed	1 hr
Wind direction	1 hr
Lake withdrawal temperature	24 hr
Lake water surface elevation	24 hr

The slowly-changing variables such as water surface temperature were sampled at intervals of 1 hour or more, while rapidly-changing variables such as solar radiation and flat plate temperature were sampled every 6 minutes. TSP's 1 and 2 were also computed using a 12-minute sampling interval. The difference in computed evaporation was negligible, being less than 0.02 inch for TSP 1 and less than 0.005 inch for TSP 2. Also, as a further check on the adequacy of data sampling and of the computer programs, the energy budget terms for August 2, 1965, were computed using the Amsler method and the computer method. The average water surface temperature and the average relative humidity were identical by both methods. The sums of $Q_a + Q_s$ differed by 1.7 percent, and Q_{bs} varied by 0.2 percent. Q_{ar}, Q_r and Bowen ratio were essentially identical.

Space limitations do not permit a complete discussion of the mechanics of the data processing and the Fortran computer programs used with the IBM 1410, 1620, and 7040 computers. A detailed description of data processing techniques and a listing of computer programs is contained in the 1965-66 Lake Hefner Report (8).

Discussion of Individual Terms in the Energy Budget

All relevant energy budget terms for 1965 and 1966 are summarized by TSP in Table VI. A daily energy budget summary table for 1966 is also included in the Appendix.

As will be shown in Chapter VIII, the energy budget evaporation exceeded the water budget evaporation by an average of approximately 20 percent. The purpose of this section is to evaluate each of the energy budget parameters and to locate, if possible, the parameter or parameters responsible for discrepancies of this magnitude.

The relative importance of each term may be seen by substituting each term for TSP 1, 1966, into the energy budget equation.

$$E = \frac{Q_s + Q_a - Q_r - Q_{ar} - Q_{bs} + Q_v - Q_o}{[L\ (1 + R) + c\ T_o]} \qquad (9)$$

$$E = \frac{4118 + 5628 - 266 - 169 - 6162 + 10 - 102}{[582.8\ (0.989) + 23.77]} = \frac{3057}{600}$$

$$E = 5.1 \text{ cm}$$

A 20 percent error in evaporation would be equivalent to an error of 611 cal/cm^2 or 87 cal/cm^2 day for TSP 1. Each of the terms in the energy budget will be examined as a possible source of error.

TABLE VI

ENERGY BUDGET EVAPORATION SUMMARY FOR LAKE HEFNER, 1965-66

TSP	Q_s	Q_r	Q_a	Q_{ar}	Q_{bs}	Q_v	Q_o	Q_e	Q_n	T_o	T_a	RH	R	EVAPORATION			
	cal/cm^2 day									°C		pct		in	cm	in/day	cm/day
1965																	
1	603.61	37.53	872.89	26.19	881.97	15.32	114.36	443.94	530.81	23.70	24.73	66.20	-0.068	2.05	5.20	0.30	0.76
2	545.70	35.73	871.15	26.13	906.50	219.22	288.85	338.84	448.48	25.70	24.28	71.90	0.074	1.61	4.09	0.23	0.58
3	608.02	37.66	863.55	25.91	903.13	405.62	438.63	447.87	504.88	25.40	25.22	64.80	0.010	2.13	5.40	0.30	0.77
4	604.05	37.54	902.75	27.08	904.84	205.84	294.80	473.52	537.34	25.60	27.19	63.70	-0.097	2.26	5.73	0.32	0.82
5	592.32	37.19	893.80	26.81	921.27	-8.11	30.81	477.10	500.85	26.90	28.72	55.10	-0.078	2.27	5.77	0.32	0.82
6	588.06	37.06	918.74	27.56	926.00	-19.65	-0.47	542.04	516.18	27.30	30.31	52.40	-0.130	2.58	6.55	0.37	0.94
7	607.18	37.63	910.35	27.31	932.86	-24.88	-69.29	599.54	519.73	27.90	30.89	46.70	-0.107	2.86	7.26	0.41	1.04
8	511.05	34.56	908.98	27.27	930.80	-5.30	14.71	415.45	427.40	27.70	29.09	61.40	-0.067	1.97	5.01	0.28	0.72
9	586.36	37.01	849.02	25.47	922.81	-6.13	-130.94	540.05	450.10	27.10	26.46	47.70	0.018	2.58	6.55	0.37	0.93
10	543.53	35.66	862.41	25.87	921.30	-5.18	-50.43	438.05	423.12	26.90	26.39	65.25	0.023	2.08	5.28	0.30	0.76
11	553.97	36.00	888.49	26.65	914.66	-4.73	58.29	421.82	465.15	26.40	27.55	72.30	-0.092	1.97	5.00	0.29	0.73
12	533.15	35.31	895.08	26.85	919.07	-5.16	-29.06	491.01	446.99	26.80	28.11	69.40	-0.087	2.67	6.78	0.33	0.85
13	529.14	35.18	848.69	25.46	902.88	3.48	-60.12	466.90	414.31	25.40	25.82	62.10	-0.020	1.58	4.01	0.32	0.80
14	515.98	34.73	900.53	27.02	914.71	0.13	110.72	350.74	440.06	26.40	28.63	56.40	-0.106	0.95	2.41	0.24	0.61
15	497.92	34.10	864.46	25.93	906.59	-4.12	-312.88	763.22	395.77	25.70	28.36	51.20	-0.121	3.22	8.17	0.52	1.32
16	377.95	29.23	738.58	22.16	853.99	0.46	-248.32	380.59	211.14	21.30	17.69	63.70	0.172	2.01	5.11	0.26	0.65
17	317.53	26.23	746.81	22.40	836.66	0.07	-102.06	251.99	179.04	19.80	18.32	58.40	0.082	1.35	3.42	0.17	0.43
18	328.63	26.82	708.33	21.25	829.67	3.28	-110.55	260.84	159.22	19.20	19.01	63.20	0.014	2.30	5.83	0.18	0.45
1966																	
1	590.76	38.16	807.44	24.23	883.93	1.42	14.65	425.98	451.91	23.77	23.96	52.29	-0.011	2.01	5.11	0.29	0.73
2	665.68	42.25	855.85	25.68	887.59	-23.87	79.75	540.63	566.02	24.15	27.03	55.69	-0.186	2.57	6.53	0.37	0.93
3	659.30	42.73	882.23	26.47	915.90	-30.08	89.16	466.36	556.44	26.48	29.07	50.03	-0.108	2.57	6.52	0.32	0.81
4	644.46	42.73	902.43	27.07	926.76	-34.52	72.10	435.02	550.34	27.37	30.27	52.87	-0.121	1.74	4.43	0.30	0.75
5	523.44	36.05	908.09	27.24	935.99	341.04	339.96	423.27	432.24	28.12	28.97	61.11	-0.023	3.77	9.57	0.29	0.73
6	563.97	38.25	920.23	27.60	936.10	-9.98	54.14	401.99	482.25	28.13	29.60	60.64	-0.064	2.22	5.64	0.27	0.70
7	587.60	40.88	845.08	25.36	938.26	-28.73	-85.23	459.33	428.19	28.29	26.46	56.34	0.056	2.21	5.62	0.31	0.79
8	539.05	38.76	874.96	26.25	928.54	-12.27	3.14	386.34	420.47	27.52	27.35	66.05	0.010	1.89	4.80	0.26	0.67
9	400.89	29.22	801.31	24.03	910.16	12.15	-242.21	406.12	238.79	26.02	21.50	73.60	0.171	2.41	6.12	0.28	0.70
10	476.60	35.22	879.00	26.37	899.55	-4.67	94.20	281.25	394.48	25.15	24.50	76.41	0.044	1.22	3.09	0.19	0.48
11	401.16	30.86	794.90	23.85	905.88	-10.63	-87.16	293.21	235.46	25.66	21.45	73.64	0.178	1.59	4.03	0.20	0.51
12	339.68	25.75	748.24	22.45	879.37	44.52	-160.39	286.70	160.35	23.46	18.70	78.69	0.234	1.74	4.42	0.19	0.49
13	420.55	32.62	760.32	22.81	869.70	-9.09	-87.87	318.00	255.73	22.69	20.46	62.35	0.105	1.72	4.36	0.22	0.55
14	345.56	27.07	707.38	21.22	838.80	-12.71	-411.87	485.00	165.85	19.97	16.66	56.64	0.132	2.28	5.79	0.33	0.83
15	404.88	30.78	699.23	20.97	825.01	-13.91	-113.96	577.33	227.34	18.77	19.43	56.43	-0.465	3.44	8.74	0.39	0.99

Solar, Atmospheric, and Back Radiation - Q_s, Q_a, and Q_{bs}

The seasonal variations and relative magnitudes of Q_{bs}, Q_a, Q_s, Q_{ar}, and Q_r are shown in Figure 17. Q_{bs} was the largest term in the energy budget, but it is not considered to be a source of large errors. In the daily instrument checks the water surface temperature recorder and the mercury in glass thermometer usually agreed within 0.5°C. An error of this magnitude would change Q_{bs} only 6 cal/cm^2 day.

The solar radiation Q_s was measured by the Eppley pyrheliometer. Although the Q_s values shown in the energy budget table appear sizeable, this is somewhat misleading. Essentially Q_s was subtracted from the flat plate output, then used to compute Q_r, and then added back into the energy budget equation. The terms Q_s, Q_a, Q_{ar}, and Q_r are interrelated as follows:

$$Q_a = \text{flat plate output} + \text{flat plate back radiation} - Q_s \quad (38)$$

$$Q_{ar} = 0.03\ Q_a \quad (39)$$

$$Q_r = 0.57456Q_s + 0.1166Q_s - 0.0001414Q_s^2 + 0.00000009927Q_s^3 - 0.00000000002818Q_s^4 \quad (40)$$

The above equation relating Q_r and Q_s was derived by fitting a polynomial equation to Koberg's (22) curve of reflected radiation for cloudy days, using the Lake Hefner latitude. Since Q_r and Q_{ar} were both very small terms, never larger than 43 cal/cm^2 day, the most probable source of error in the radiation terms is Q_a.

The flat plate radiometer was quite sensitive to changes in the wind speed and direction. During clear, gusty days, the flat plate trace characteristically had a sawtooth pattern while the Eppley pyrheliometer had a smooth output pattern. Since the flat plate

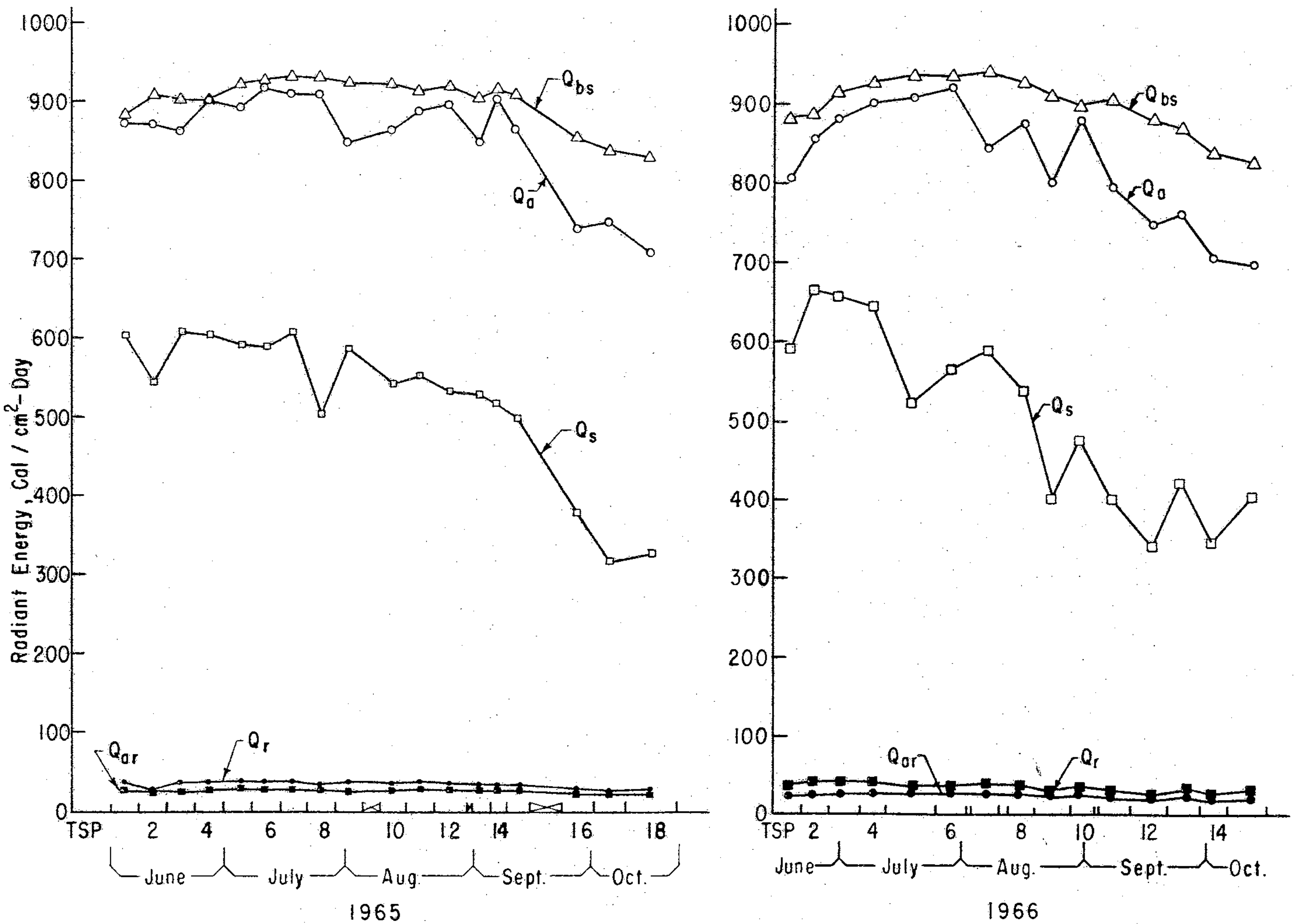

Figure 17. Variation of the Radiation Terms in the Energy Budget Equation at Lake Hefner During 1965 and 1966.

radiometer requires a constant ventilation rate, a sizeable error may result under windy conditions.

The flat plate output was also subject to error during rainy weather. When the sensing element was wetted by rain the output was always lower. During night rains this discrepancy could be corrected by connecting the traces before and after the rain with a straight line, and this was done for the 1966 data. Discrepancies during daytime rains were more difficult to estimate. In an attempt to correct for the error on rainy days a relationship was developed between the outputs of the south station flat plate radiometer and the south station Eppley pyrheliometer. The data were examined for six days in 1966 (July 15, August 5, 8, 13, 27, and September 1) and the following relationship determined:

$$\text{Flat plate output} = -0.1014 + 2.6553 \times \text{Eppley output} \quad \text{(Millivolts)} \qquad (41)$$

The correlation coefficient R was 0.93 and the standard deviation was 0.46. This relationship was used on a few of the most rainy days in 1966 to adjust the flat plate output.

The flat plate radiometer at the intake tower was used only as a back-up instrument to fill in missing data at the south station. A check of the two instruments was made using the data for July 11, 1966. The Q_a observed at the intake tower was 883 cal/cm^2 day compared with 889 cal/cm^2 day at the south station, a difference of less than 1 percent.

The values of Q_a and Q_s obtained in 1965 and 1966 are compared in Figure 18 with those obtained in the 1950-51 Lake Hefner Investigation.

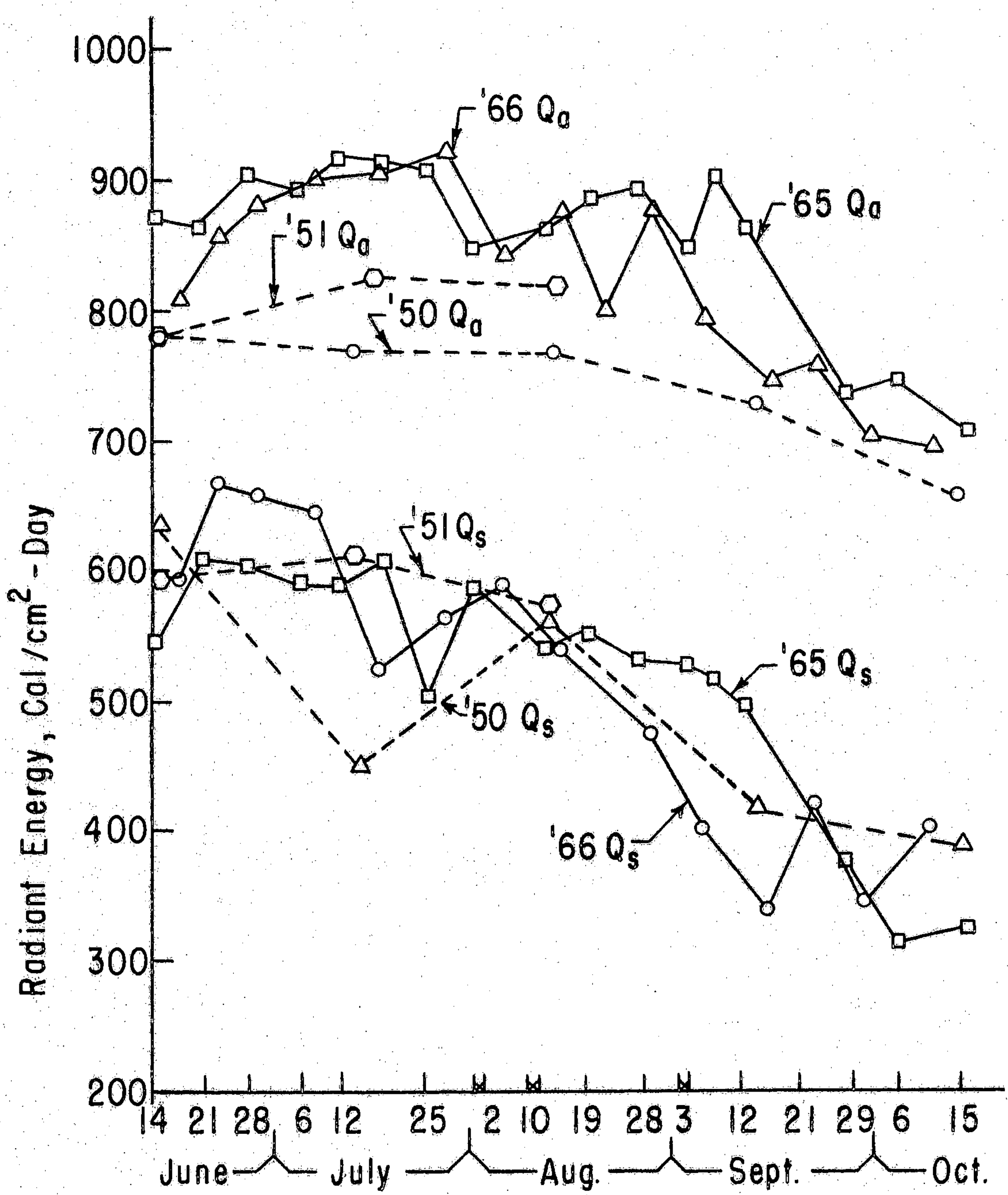

Figure 18. Solar and Atmospheric Radiation at Lake Hefner for 1950-51 and 1965-66.

The values of Q_s appear to be about the same order of magnitude for all four years. However, Q_a was higher in both 1965 and 1966 than in 1950 and 1951. This difference is significant in view of the fact that in 1950-51 the energy budget and water budget evaporation amounts were equal, but in the 1965-66 study the energy budget evaporation was approximately 20 percent higher than the water budget evaporation

Advected Energy - Q_v

The mass curves of advected energy, Q_v, for 1965 and 1966 are shown in Figure 19. The relative magnitude of the various terms that make up the advected energy can best be seen in the water budget summary. In 1965 advected energy items accounted for the following stage changes: inflow, 7.7 feet; water plant withdrawals, 1.5 feet; rain, 0.7 foot; seepage, 0.09 foot; irrigation, 0.06 foot. The same order of ranking holds for 1966.

Although inflow was the largest term, most of the inflow occurred during four relatively short periods. Inflow was a small item during the balance of the study period. Hence water plant withdrawals and rain must have accounted for most of the advected energy during periods of little or no inflow.

Excluding periods of high inflow, Q_v was less than 44 cal/cm^2 day during both years. The water plant withdrawals were subject to an estimated ±3 percent error in volume measurements.* Outflow temperature errors could not be determined, but assuming these to be as high as 2°F would cause an error of only 1.5 percent in Q_v. Similarly, an error of

*Estimate by Water Plant personnel.

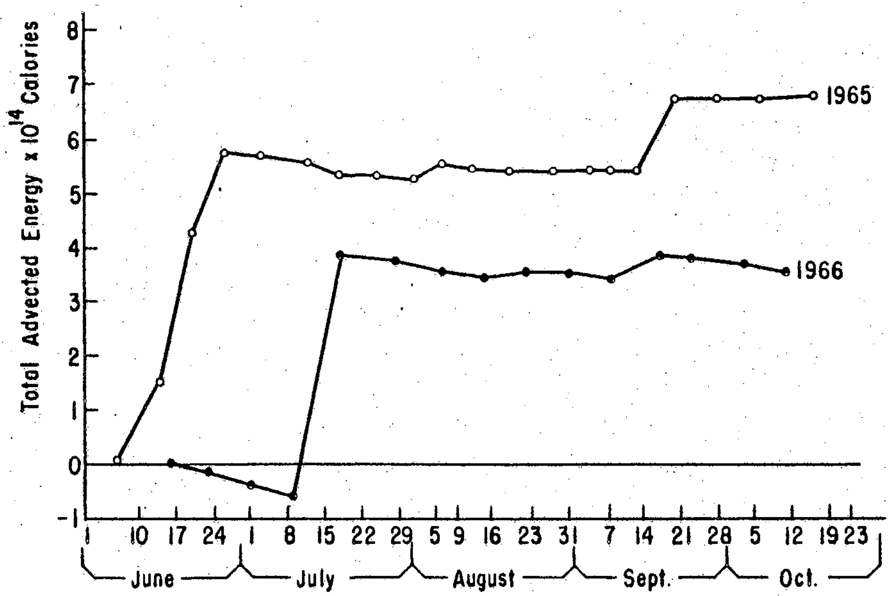

Figure 19. Mass Curves of the Total Advected Energy for Lake Hefner During 1965-66.

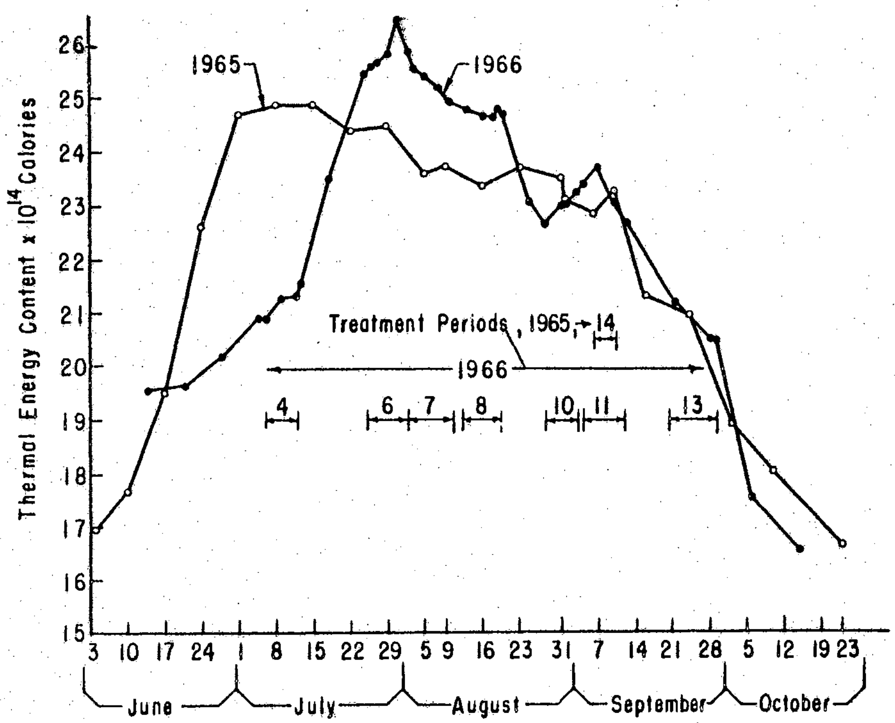

Figure 20. Mass Curves of the Thermal Energy Content of Lake Hefner During the 1965-66 Investigation. Numerals Indicate TSP's when Alcohol was Applied.

2°F in rainfall temperatures would cause an error in Q_v of only about 0.75 percent, on the average.

Possible errors in Q_v due to rainfall may include gage errors, inadequate numbers of gages, or runoff. The likelihood of errors in gage measurement is small because of frequent checking. Errors due to runoff were discussed with the water budget parameters. Q_v is itself a small term, and since rain accounts for only about one-third of Q_v, it is believed that errors due to rain were small except possibly during periods of heavy rain.

As previously noted the accuracy of the inflow measurement is low during periods of high inflow rates. For example, the water budget for TSP 2, 1965, showed a negative evaporation, -0.18 inch, and a stage change due to inflow of 23.0 inches. The negative evaporation may be rejected as an impossibility. By comparison with other TSP's the actual evaporation may have been about 2 inches. With this assumption the inflow must have been about 25 inches. Thus it appears that during periods of high inflow the measurements may be in error in the order of 8 percent. For TSP 2, which had a Q_v of 219 cal/cm^2 day, this would represent an error of 18 cal/cm^2 day. Apparently the energy budget is subject to greater error than normal during periods of high inflow, but it is not quite so sensitive to inflow errors as the water budget.

<u>Stored Energy - Q_o</u>

Table VII shows the lake stage, area, surface temperature, weighted average temperature, and total energy content of the lake for each thermal survey in 1965 and 1966. The mass curves of advected energy, Q_v, and stored energy, Q_o, are shown in Figures 19 and 20. The rapid

TABLE VII

STORED ENERGY IN LAKE HEFNER, BY THERMAL SURVEYS

Date	Lake Stage feet	Lake Area acres	Surface Temp °C	Wt Avg Temp °C	Stored Energy cal
1965					
06/03/65	1192.45	2236.53	23.97	23.21	0.16953396E 16*
06/10/65	1192.47	2237.73	24.06	23.99	0.17658032E 16
06/17/65	1194.43	2331.53	24.99	24.69	0.19521202E 16
06/24/65	1197.77	2490.22	25.37	25.28	0.22502904E 16
07/01/65	1199.37	2566.13	26.45	26.20	0.24640116E 16
07/08/65	1199.15	2555.45	28.05	26.80	0.24863489E 16
07/15/65	1198.80	2539.00	27.12	25.86	0.24860051E 16
07/22/65	1198.39	2519.64	26.92	25.78	0.24363437E 16
07/29/65	1198.21	2511.10	27.05	26.97	0.24467839E 16
08/05/65	1197.96	2499.24	26.20	26.19	0.23535909E 16
08/07/65	1198.21	2511.10	26.03	25.69	0.23285352E 16
08/09/65	1198.24	2512.52	27.71	26.32	0.23675124E 16
08/16/65	1198.05	2503.51	25.92	25.90	0.23317816E 16
08/20/65	1197.95	2498.76	26.24	26.14	0.23463940E 16
08/23/65	1197.88	2495.68	26.83	26.52	0.23723138E 16
08/30/65	1197.67	2485.48	26.24	26.32	0.23411987E 16
08/31/65	1197.65	2484.77	26.38	26.41	0.23488807E 16
09/01/65	1197.67	2485.48	25.89	25.95	0.23099362E 16
09/05/65	1197.59	2481.68	25.45	25.41	0.22554530E 16
09/06/65	1197.58	2481.21	25.81	25.75	0.22798565E 16
09/08/65	1197.55	2479.79	26.54	26.26	0.23172515E 16
09/10/65	1197.52	2478.36	26.73	26.41	0.23240815E 16
09/16/65	1197.28	2466.98	24.20	24.22	0.21296401E 16
09/24/65	1199.29	2562.33	22.23	22.26	0.20946187E 16
10/02/65	1199.08	2552.37	20.36	20.28	0.18932783E 16
10/10/65	1198.99	2548.10	19.74	19.51	0.18096713E 16
10/23/65	1198.84	2540.98	17.93	17.92	0.16609790E 16
1966					
06/14/66	1196.12	2412.04	23.92	23.33	0.19542661E 16
06/17/66	1196.20	2415.51	23.16	23.14	0.19561410E 16
06/21/66	1196.05	2408.63	23.38	23.37	0.19642283E 16
06/28/66	1195.65	2389.60	24.34	24.33	0.20185770E 16
07/05/66	1195.27	2371.48	26.50	25.79	0.20915318E 16
07/06/66	1195.19	2367.69	26.53	25.82	0.20881343E 16
07/09/66	1194.99	2358.34	27.34	26.58	0.21350603E 16
07/12/66	1194.76	2347.33	27.04	25.63	0.21285324E 16
07/13/66	1194.74	2346.37	27.50	26.98	0.21526558E 16
07/18/66	1196.68	2438.51	29.02	27.73	0.23501332E 16
07/25/66	1199.40	2567.36	27.62	27.11	0.25444087E 16
07/26/66	1199.41	2567.84	27.50	27.19	0.25577075E 16
07/27/66	1199.45	2569.92	28.12	27.32	0.25657346E 16
07/29/66	1199.27	2561.38	28.65	27.72	0.25797894E 16
07/31/66	1199.28	2561.86	30.72	28.70	0.26480453E 16
08/02/66	1199.16	2556.17	28.49	27.86	0.25897986E 16
08/03/66	1199.09	2552.84	28.17	27.53	0.25546405E 16
08/05/66	1198.97	2547.15	27.92	27.44	0.25377338E 16
08/08/66	1198.74	2536.24	28.11	27.49	0.25188268E 16
08/10/66	1198.69	2533.87	28.28	27.28	0.24927353E 16
08/12/66	1198.60	2529.60	27.47	27.09	0.24768393E 16
08/16/66	1198.42	2521.06	27.03	27.06	0.24647998E 16
08/18/66	1198.28	2514.42	27.62	27.22	0.24611748E 16
08/19/66	1198.43	2521.53	27.84	27.31	0.24791470E 16
08/20/66	1198.49	2524.38	27.21	27.05	0.24703532E 16
08/25/66	1198.53	2526.28	25.25	25.20	0.23066319E 16
08/28/66	1198.42	2521.06	24.74	24.78	0.22629144E 16
08/29/66	1198.40	2520.11	24.89	24.82	0.22620123E 16
08/31/66	1198.40	2520.11	25.44	25.25	0.22983113E 16
09/01/66	1198.38	2519.16	25.82	25.33	0.23003589E 16
09/03/66	1198.33	2516.79	26.13	25.67	0.23240800E 16
09/04/66	1198.36	2518.21	26.42	25.82	0.23363518E 16
09/07/66	1198.28	2514.42	26.60	26.02	0.23724651E 16
09/10/66	1198.20	2510.62	25.95	25.55	0.23047595E 16
09/12/66	1198.14	2507.78	25.31	25.11	0.22657624E 16
09/21/66	1198.72	2535.29	24.64	23.23	0.21183294E 16
09/24/66	1198.62	2530.55	22.76	22.84	0.21016450E 16
09/28/66	1198.56	2527.70	23.36	22.55	0.20498905E 16
09/29/66	1198.53	2526.28	23.84	22.62	0.20466492E 16
10/06/66	1198.20	2510.62	19.56	19.42	0.17546100E 16
10/15/66	1197.85	2494.02	18.41	18.46	0.16527781E 16

*E 16 is equivalent to 10^{16}

build up in both stored energy and advected energy in June, 1965 and July, 1966 coincides with the filling of the lake.

Previous investigators have theorized that the determination of changes in Q_0 could cause sizeable errors in the energy budget. However, an examination of the data from Lake Hefner shows that this is not necessarily true. For example, during TSP 1, 1966, the change in stored energy was 102.1 cal/cm^2 or 14.6 cal/cm^2 day. An error of 0.1°C in the weighted average temperature of the lake during the ending thermal survey would have caused a total error of 76 cal/cm^2 or about 11 cal/cm^2 day. This would have changed the computed energy budget evaporation 0.13 cm or about 2.5 percent.

Errors in the change of stored energy at Lake Hefner due to errors in measurement of stage change were considered to be very small due to the good quality of stage records and the slowly changing stage. However, this could be a very large error at a lake with a rapidly changing stage.

The most convincing evidence that errors in measuring changes in the stored energy are a small source of errors in the Lake Hefner energy budget is that the energy budget evaporation consistently exceeded the water budget evaporation, whereas a positive error in Q_0 for one TSP would necessarily result in a negative error in Q_0 for the next TSP. In other words, the errors in Q_0 are not cumulative, as they are for all other terms in the energy budget.

Lake temperature profiles as determined from the thermal surveys are plotted in Figures 21 and 22. The figures are arranged to show the seasonal increase and decrease in lake temperature. The lake exhibited an almost isothermal profile during the spring. During the season of

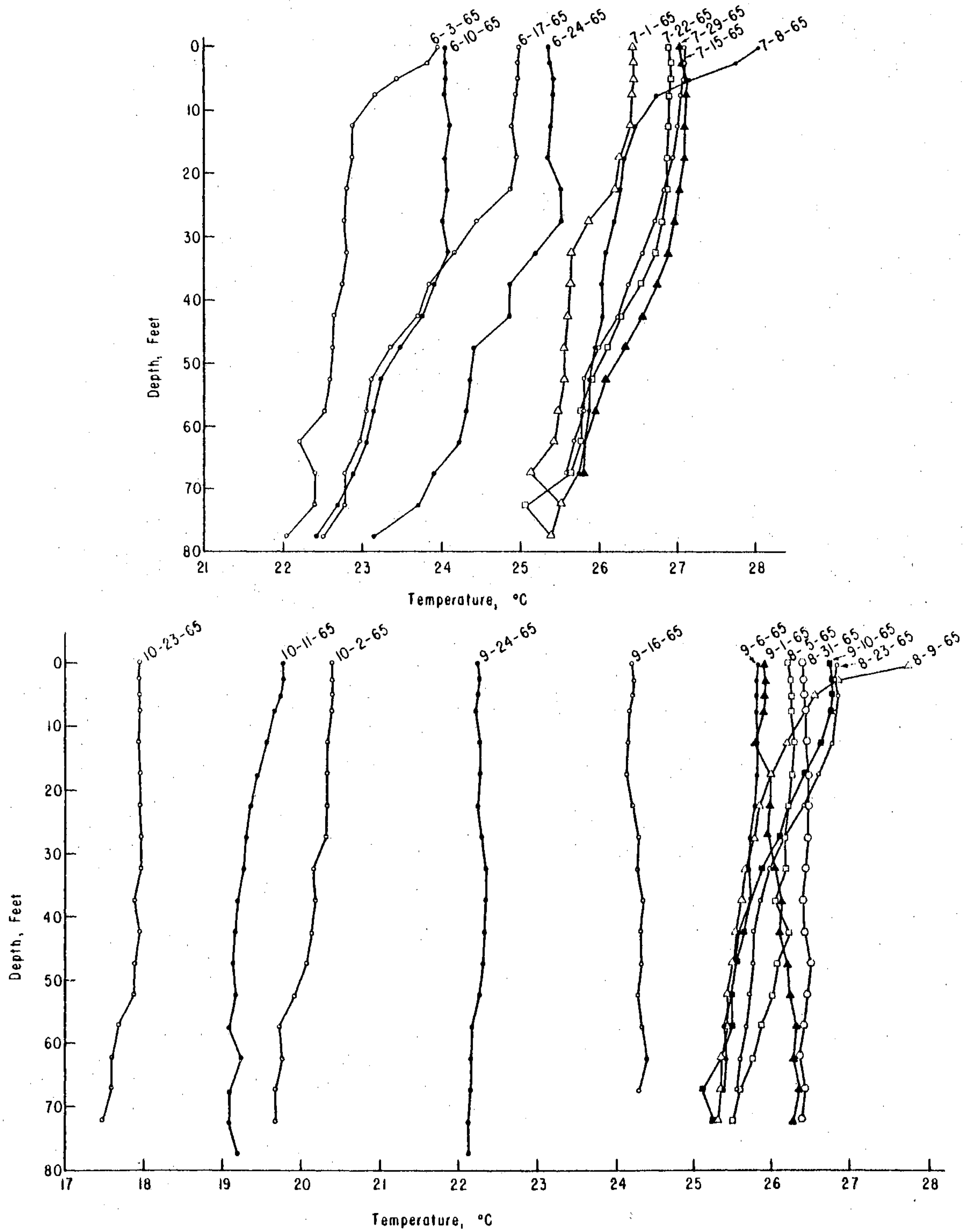

Figure 21. Lake Temperature Profiles for the 1965 Lake Hefner Investigation.

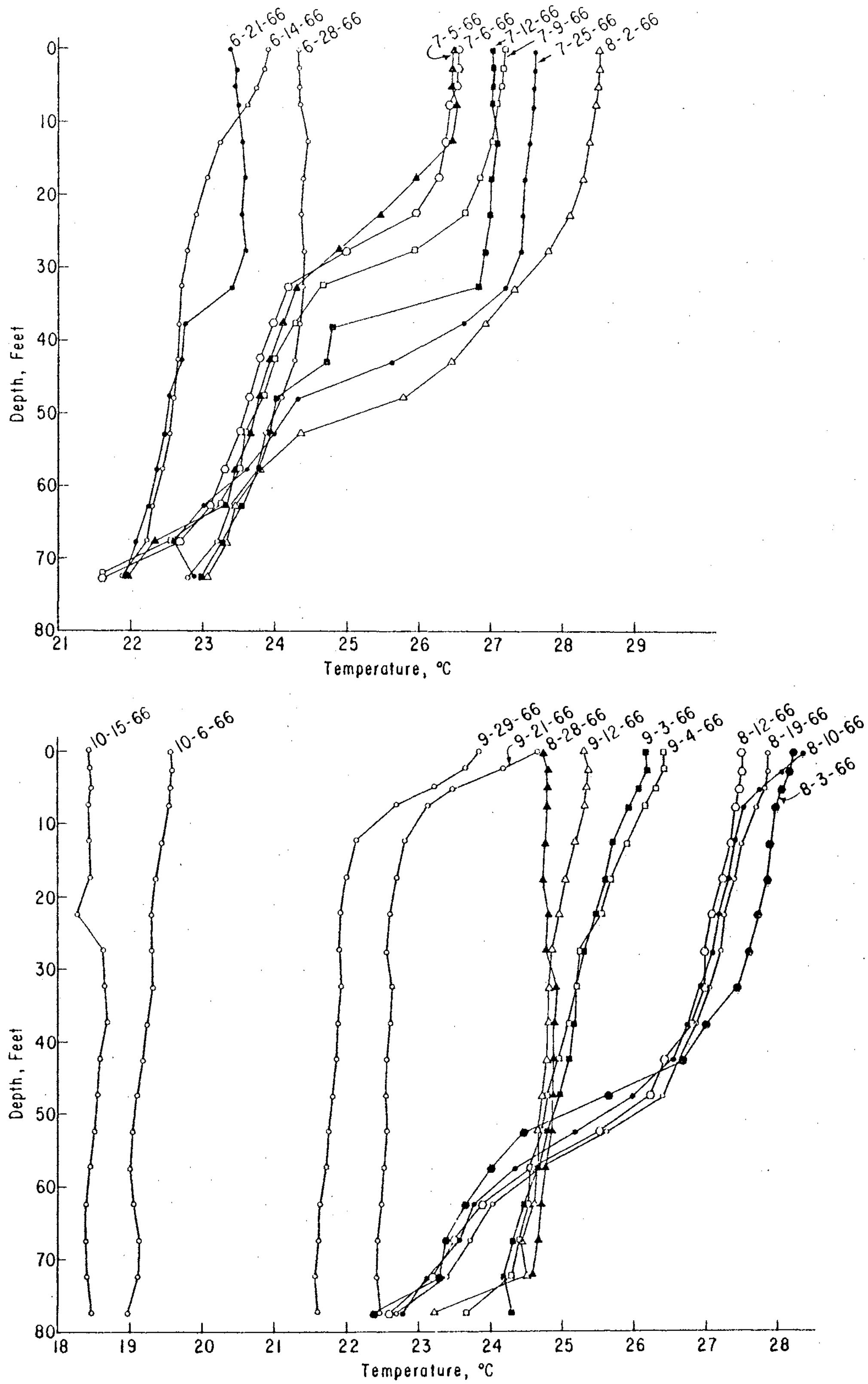

Figure 22. Lake Temperature Profiles for the 1966 Lake Hefner Investigation.

maximum solar radiation the lake warmed and reached a peak temperature during late July or early August. The surface was warmed more than the bottom, and by mid-August there was as much as 5°C difference between the surface and bottom of the lake. The cooling trend usually began in August and by mid-October the lake had cooled and assumed its isothermal profile.

The thermal surveys on any two consecutive days, such as September 3 and 4, 1966, usually were quite similar. This was regarded as a good check on the accuracy of the thermal surveys.

Air and Water Surface Temperature and Relative Humidity - T_a, T_o, and RH

The average air and water surface temperatures and relative humidities for each TSP in 1965 and 1966 are shown in the energy budget summary table, and are plotted in Figure 23.

The seasonal variations of T_o and Q_o were somewhat similar, but the maximum lake surface temperature typically occurred a few days before the maximum stored energy. The maximum average lake surface temperature for an entire TSP in 1965 was 27.90°C (TSP 7) compared with 28.29°C in 1966 (TSP 7). There was an increase in T_o during both TSP 14, 1965, and TSP 11, 1966, which were the two periods of greatest film cover on the lake. This is especially significant in 1966 because TSP 11 occurred during a period of normally declining lake surface temperatures. It seems possible that the increase in T_o was due to the presence of the film cover.

The seasonal variation of the air temperature, T_a, was quite different for each of the two years. T_a reached a peak of 30.89°C in July, 1965, and then declined somewhat before reaching a secondary

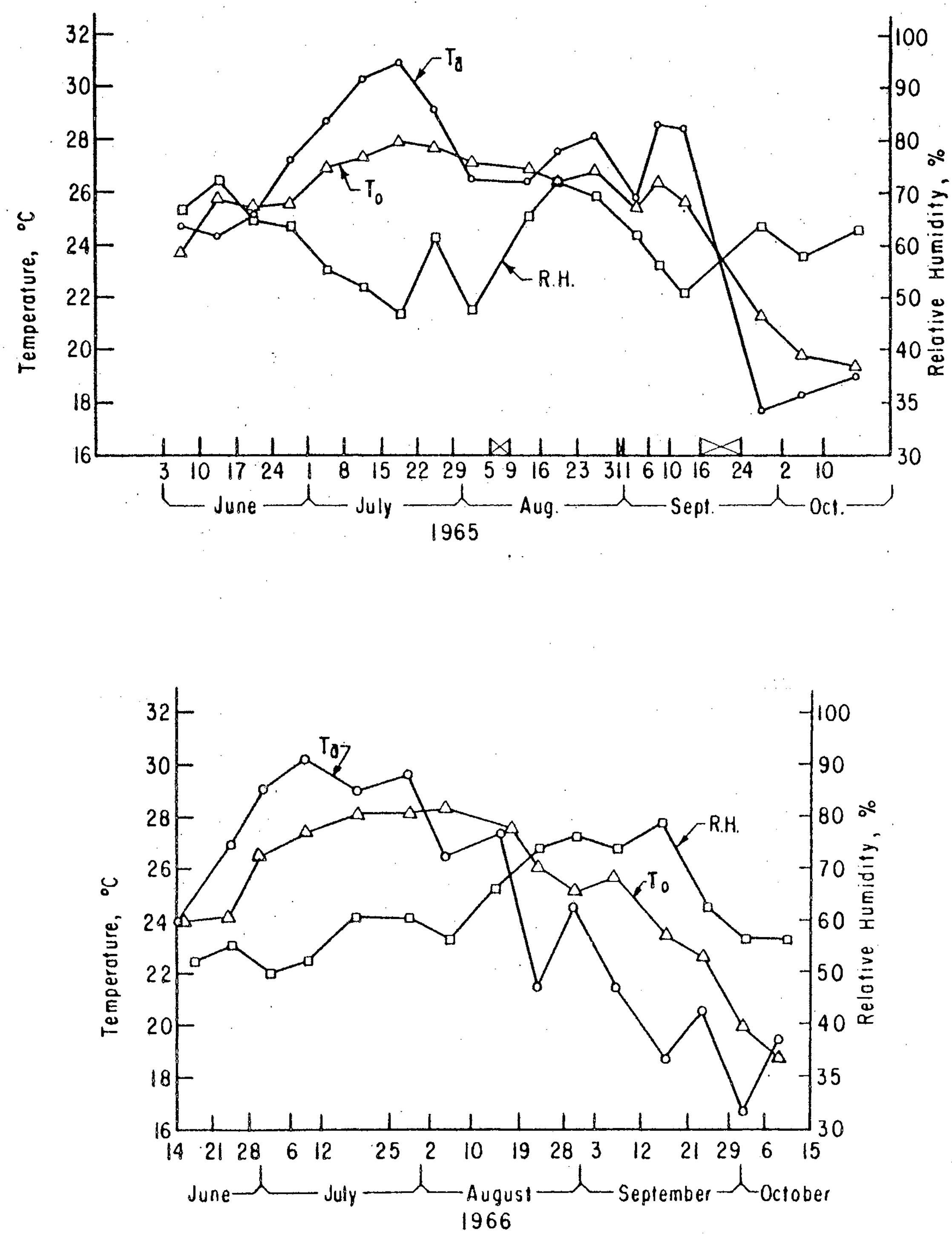

Figure 23. Variation of the Air and Water Surface Temperatures and the Relative Humidity at Lake Hefner for 1965 and 1966.

peak of 28.63°C in September, 1965. In 1966 T_a reached a peak of 30.27°C in July and then declined sharply during a cool, rainy period in mid-August.

The seasonal variation of the relative humidity also was quite different for the two years. During 1965 the relative humidity reached its seasonal low of 46.70 percent in July and its high of 69.40 percent in late August, while in 1966 it reached its seasonal low of 50.03 percent in early July and its high of 78.69 percent in mid-September.

Reduction of Relative Humidity Data

During the periods June 3 to October 23, 1965, and June 14 to July 17, 1966, the 2-meter relative humidity was recorded with a lithium chloride hygrometer. The average relative humidity for each TSP was scaled from the recorder chart using the Amsler integrator in 1965 and using the computer and a 30-minute data sampling interval in 1966. Beginning on July 17, 1966, a wet bulb-dry bulb thermocouple psychrometer was substituted for the lithium chloride hygrometer.

The reduction of the relative humidity data and the computation of e_o and e_a was done using standard methods described in the Smithsonian Meteorological Tables (46). In order to store the relationship between e_o and T_o in the computer, a curve fit program was fitted to data from Table No. 95 of the Smithsonian Meteorological Tables to yield the following relationship:

$$e_o = 6.23814 + 0.4101179T_o + 0.0175476T_o^2 + 0.0001184T_o^3 + 0.00000604T_o^4 \quad (42)$$

The relative humidity, e_a, e_o, and $(e_o - e_a)$ for each TSP in 1965 are shown in the Bowen ratio summary, Table VIII. Daily values of the

TABLE VIII

TABULATION OF PERTINENT QUANTITIES AND CALCULATION OF BOWEN'S RATIO, R, BY THERMAL SURVEY PERIODS FOR LAKE HEFNER

1965

TSP	Avg T_o	Avg T_a	Avg RH	Avg e_o	Avg e_s	Avg e_a	$\Delta T = T_o - T_a$	$\Delta e = e_o - e_a$	P	R
	°C	°C	%	mb	mb	mb	°C	mb	mb	
1	23.7	24.7	66.2	29.298	31.109	20.59	-1.0	8.71	970.14	-0.068
2	25.7	24.3	71.9	33.016	30.373	21.84	1.4	11.18	970.62	0.074
3	25.4	25.2	64.8	32.434	32.050	20.77	0.2	11.66	974.07	0.010
4	25.6	27.2	63.7	32.821	36.070	22.98	-1.6	9.84	974.34	-0.097
5	26.9	28.7	55.1	35.440	39.365	21.69	-1.8	13.75	972.14	-0.078
6	27.3	30.3	52.4	36.282	43.166	22.62	-3.0	13.66	972.14	-0.130
7	27.9	30.9	46.7	37.576	44.672	20.86	-3.0	16.72	973.16	-0.107
8	27.7	29.1	61.4	37.140	40.287	24.74	-1.4	12.40	973.73	-0.067
9	27.1	26.5	47.7	35.859	34.615	16.51	0.6	19.35	973.43	0.018
10	26.9	26.4	65.2	35.440	34.411	22.45	0.5	12.99	974.92	0.023
11	26.4	27.6	72.3	34.411	36.924	26.70	-1.2	7.71	971.53	-0.092
12	26.8	28.1	69.4	35.232	38.017	26.38	-1.3	8.85	971.90	-0.087
13	25.4	25.8	62.1	31.434	33.212	20.62	-0.4	11.81	971.63	-0.020
14	26.4	28.6	56.4	34.411	39.137	22.07	-2.2	12.34	973.49	-0.106
15	25.7	28.4	51.2	33.016	38.686	19.81	-2.7	13.21	969.40	-0.121
16	21.3	17.7	63.7	25.323	20.244	12.90	3.6	12.42	974.24	0.172
17	19.8	18.3	58.4	23.085	21.023	12.28	1.5	10.80	973.26	0.082
18	19.2	19.0	63.2	22.240	21.964	13.88	0.2	8.36	972.95	0.014

relative humidity, e_a, e_o, and $(e_o - e_a)$ for each day in 1966 are shown in the daily energy budget summary table in the appendix. Daily checks of the relative humidity indicated that the lithium chloride hygrometers were often in error by 5 percent or more. However, the thermocouple psychrometer was seldom in error by as much as 3 percent. The lake surface temperature was checked every day that weather conditions permitted and the daily checks seldom indicated a temperature error of more than 0.5°C. Thus it appears that possible errors in e_o are small since e_o is a function of T_o alone. However, since e_a is a function of both T_a and relative humidity, it is subject to considerably more error than e_o. When these factors are taken into consideration, it appears that the value of the vapor pressure deficit term $(e_o - e_a)$ could have been in error by as much as 12 percent before July 17, 1966, and by as much as 7 percent after that date. An error in the vapor pressure deficit term, of course, directly affects the accuracy of the Bowen ratio and of the mass transfer coefficient N.

Bowen Ratio

The pertinent quantities and calculated Bowen ratios for 1965 are shown in Table VIII. In 1966 the Bowen ratios were computed for each day by the energy budget computer program. Daily and average values are listed in the 1966 energy budget summary in Appendix B. Under normal meteorological conditions the Bowen Ratio varied from -0.12 in TSP 15, 1965, to 0.23 in TSP 12, 1966.

The Bowen ratio can be a source of considerable error under certain unusual meteorological conditions. For example on

October 13, 1966, an unusually high air temperature caused by a warm, moist air mass moving into the area created unusually stable atmospheric conditions which caused the Bowen ratio to be -3.72 for that day. This in turn caused the energy budget to greatly overestimate the evaporation for TSP 15.

This problem has been discussed at length by Anderson (1) in the original Lake Hefner report. He concluded that these unusual values of the Bowen ratio seldom occur during periods of high evaporation. The trouble experienced with the Bowen ratio on October 13, 1966, is in agreement with the research of Pruitt (36) who found that the ratio of the eddy diffusivities for heat and water vapor was not unity under highly stable conditions.

Summary of Discussion of Energy Budget Parameters

The greatest single source of possible error in the energy budget was in the measurement of the atmospheric radiation, Q_a, by the flat plate radiometer. Q_{bs}, Q_r, Q_{ar}, and Q_o were negligible sources of possible error. Q_v was a potential source of error only during the rare periods of high inflows. Another potential source of error in the data was the measurement of e_a required for computation of the Bowen ratio. Also, the theoretical shortcomings of the Bowen ratio can be a source of error under certain unusual conditions of very high atmospheric stability. The above conclusions are in general agreement with those of Hughes (20) in the recently published Salton Sea report.

CHAPTER VIII

RESULTS OF LAKE EVAPORATION STUDIES

Comparison of Energy Budget and Water Budget Evaporation Rates

The average daily evaporation during each TSP, as computed by the energy budget and water budget, is listed in Table IX and is shown graphically in Figure 24.

Evaporation rates determined by the water budget for TSP's 1 to 4, 1965, and TSP 5, 1966, are of doubtful accuracy because of heavy inflow to the lake. Therefore, these periods are excluded from the totals and averages in Table IX. As previously noted, the lake was filled to capacity twice in 1965 and once in 1966. The maximum stage change was 7.0 feet during June, 1965. While these stage changes were small compared to fluctuations that are possible on some on-stream reservoirs, water budget values of evaporation were erratic during periods of inflow.

During periods of high inflow the currents in the inflow canal caused the stage recorder float to fluctuate up and down by as much as 0.1 foot. A fluctuation of ±0.1 foot when the flow was at 1.6 feet above the weir would cause the rated discharge of 575 cfs to vary between 474 and 707 cfs. As was previously mentioned on Page 77, the inflow was actually in error by as much as 8 percent during periods of high inflow.

Rains of two inches or more also caused unexplained variations in the water budget. Nevertheless, there were many periods without inflow

TABLE IX

DAILY EVAPORATION AT LAKE HEFNER COMPUTED BY ENERGY BUDGET AND WATER BUDGET METHODS

TSP	Dates	Evaporation Computation Method					
		Energy Budget			Water Budget		
		inches	cm/day	in/day	inches	cm/day	in/day
1965							
1	Jun 3 - Jun 10	2.05	0.764	0.301	0.92(a)	0.342	0.135
2	Jun 10 - Jun 17	1.61	0.584	0.230	-0.18(a)	-0.065	-0.026
3	Jun 17 - Jun 24	2.13	0.772	0.304	3.00(a)	1.089	0.429
4	Jun 24 - Jul 1	2.26	0.816	0.321	2.42(a)	0.877	0.345
5	Jul 1 - Jul 8	2.27	0.824	0.324	1.85	0.672	0.265
6	Jul 8 - Jul 15	2.58	0.936	0.369	1.98	0.718	0.283
7	Jul 15 - Jul 22	2.86	1.037	0.408	2.30	0.836	0.329
8	Jul 22 - Jul 29	1.97	0.718	0.283	1.90	0.693	0.273
9	Jul 29 - Aug 5	2.58	0.933	0.367	2.20	0.796	0.313
10	Aug 9 - Aug 16	2.08	0.756	0.298	1.60	0.584	0.230
11	Aug 16 - Aug 23	1.97	0.728	0.287	1.44	0.532	0.209
12	Aug 23 - Aug 31	2.67	0.848	0.334	2.03	0.643	0.253
13	Sep 1 - Sep 6	1.58	0.805	0.317	1.31	0.670	0.264
14	Sep 6 - Sep 10	0.95	0.605	0.238	0.74(c)	0.473	0.186
15	Sep 10 - Sep 16	3.22(b)	1.316	0.518	2.15	0.881	0.347
16	Sep 24 - Oct 2	2.01	0.653	0.257	2.31	0.750	0.295
17	Oct 2 - Oct 10	1.35	0.432	0.170	0.93	0.299	0.118
18	Oct 10 - Oct 23	2.30	0.446	0.176	2.51	0.488	0.192
Total (Excl. TSP 1-4, 15)		27.17			23.10		
Average (Excl. TSP 1-4, 15)			0.748	0.294		0.627	0.247
1966							
1	Jun 14 - Jun 21	2.01	0.732	0.288	1.44	0.526	0.207
2	Jun 21 - Jun 28	2.57	0.930	0.366	1.98	0.716	0.282
3	Jun 28 - Jul 6	2.57	0.805	0.317	1.83	0.574	0.226
4	Jul 6 - Jul 12	1.74	0.751	0.296	1.82(c)	0.785	0.309
5	Jul 12 - Jul 25	3.77	0.732	0.288	6.20(a)	1.204	0.474
6	Jul 25 - Aug 2	2.22	0.696	0.274	1.81(c)	0.566	0.223
7	Aug 3 - Aug 10	2.21	0.792	0.312	1.87(c)	0.671	0.264
8	Aug 12 - Aug 19	1.89	0.668	0.263	1.27(c)	0.450	0.177
9	Aug 19 - Aug 28	2.41	0.699	0.275	1.98	0.574	0.226
10	Aug 28 - Sep 3	1.22	0.483	0.190	0.84(c)	0.335	0.132
11	Sep 4 - Sep 12	1.59	0.505	0.199	1.23(c)	0.391	0.154
12	Sep 12 - Sep 21	1.74	0.493	0.194	1.44	0.409	0.161
13	Sep 21 - Sep 29	1.72	0.549	0.216	1.40	0.445	0.175
14	Sep 29 - Oct 6	2.28	0.831	0.327	2.07	0.754	0.297
15	Oct 6 - Oct 15	3.44(b)	0.987	0.389	1.67	0.480	0.189
16	Oct 15 - Oct 22				1.91	0.693	0.273
17	Oct 22 - Oct 29				0.84	0.305	0.120
18	Oct 29 - Nov 5				1.29	0.467	0.184
19	Nov 5 - Nov 12				0.75	0.272	0.107
20	Nov 12 - Nov 19				0.69	0.251	0.099
21	Nov 19 - Nov 27				1.07	0.340	0.134
22	Nov 27 - Dec 4				1.40	0.508	0.200
Total (Excl. TSP 5, 15-22)					20.98		
Average (Excl. TSP 5, 15-22)						0.553	0.218

(a) Lake was being refilled during these periods. Accuracy of water budget may have been affected.
(b) Accuracy of energy budget questionable during these periods.
(c) Lake was treated during these periods.

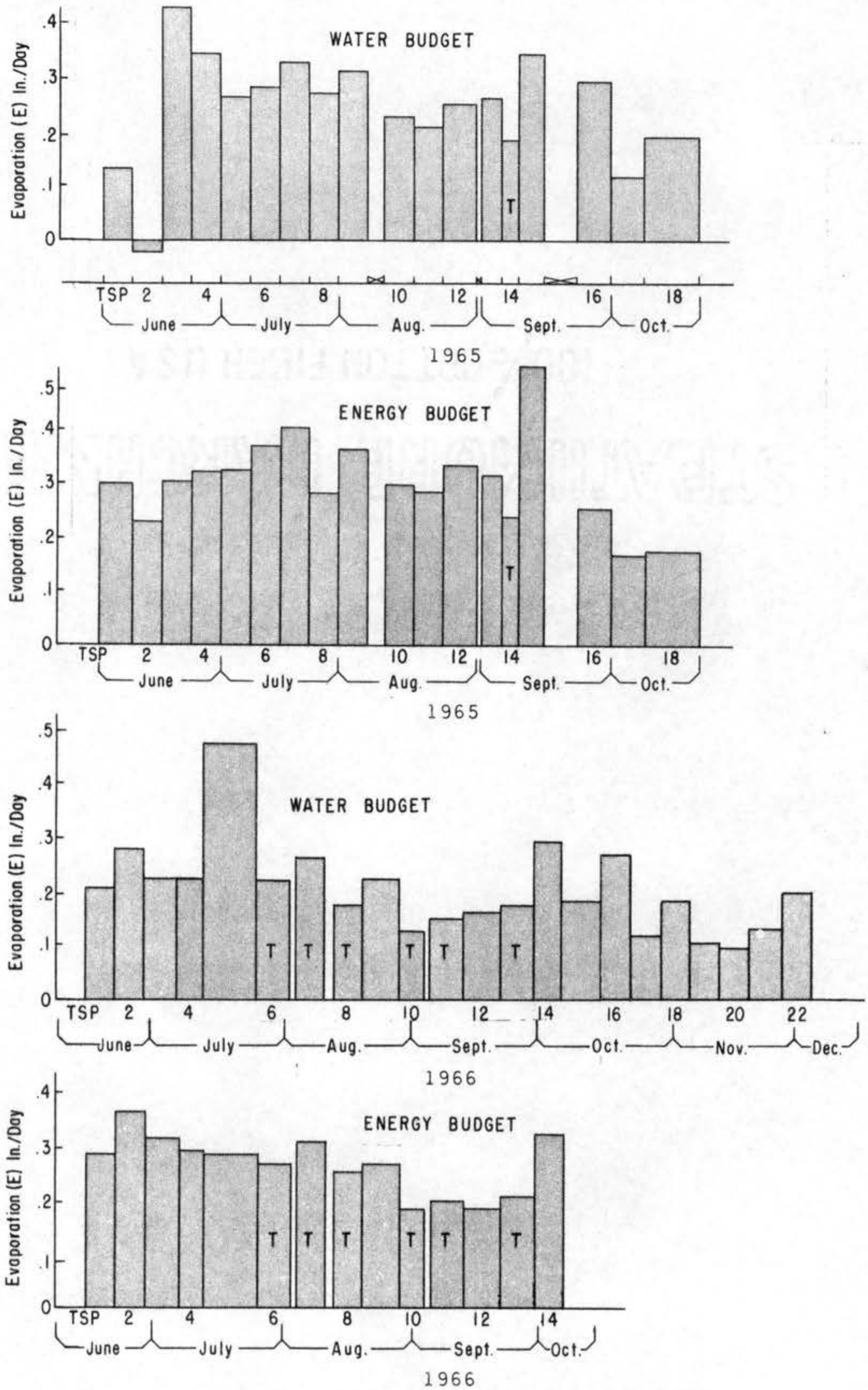

Figure 24. 1965-66 Evaporation from Lake Hefner Computed by the Water Budget and Energy Budget Methods. Treatment periods are indicated by "T".

or heavy rainfall when the water budget was considered to be an accurate standard against which the energy budget could be compared.

There was one period in each year (TSP 15 in 1965 and TSP 15 in 1966) when the energy budget evaporation rates appeared to be unreasonably high. The Bowen Ratio was probably responsible for these discrepancies. This is discussed elsewhere. In order to provide a realistic comparison of the evaporation rates computed by the two methods these two periods have been excluded from the totals and averages in Table IX.

Evaporation computed by the energy budget exceeded the water budget evaporation for the majority of the TSP's. Excluding the questionable data referred to above, and considering the water budget evaporation as the standard, the energy budget method overestimated the evaporation by 18 percent in 1965 and 24 percent in 1966.

Figure 25 shows the relation between the results of the two methods using pooled data for 1965 and 1966 with all questionable data excluded. The line of best fit is represented by the equation:

$$E_{eb} = 0.07 + 0.93\ E_{wb} \qquad \text{(1965 and 1966)} \qquad (43)$$

Although not shown in Figure 25, the equations of best fit for 1965 only and 1966 only were:

$$E_{eb} = 0.04 + 1.02\ E_{wb} \qquad (1965) \qquad (44)$$

$$E_{eb} = 0.08 + 0.85\ E_{wb} \qquad (1966) \qquad (45)$$

The reason for the consistent difference between the energy budget evaporation and the water budget evaporation is not readily apparent.

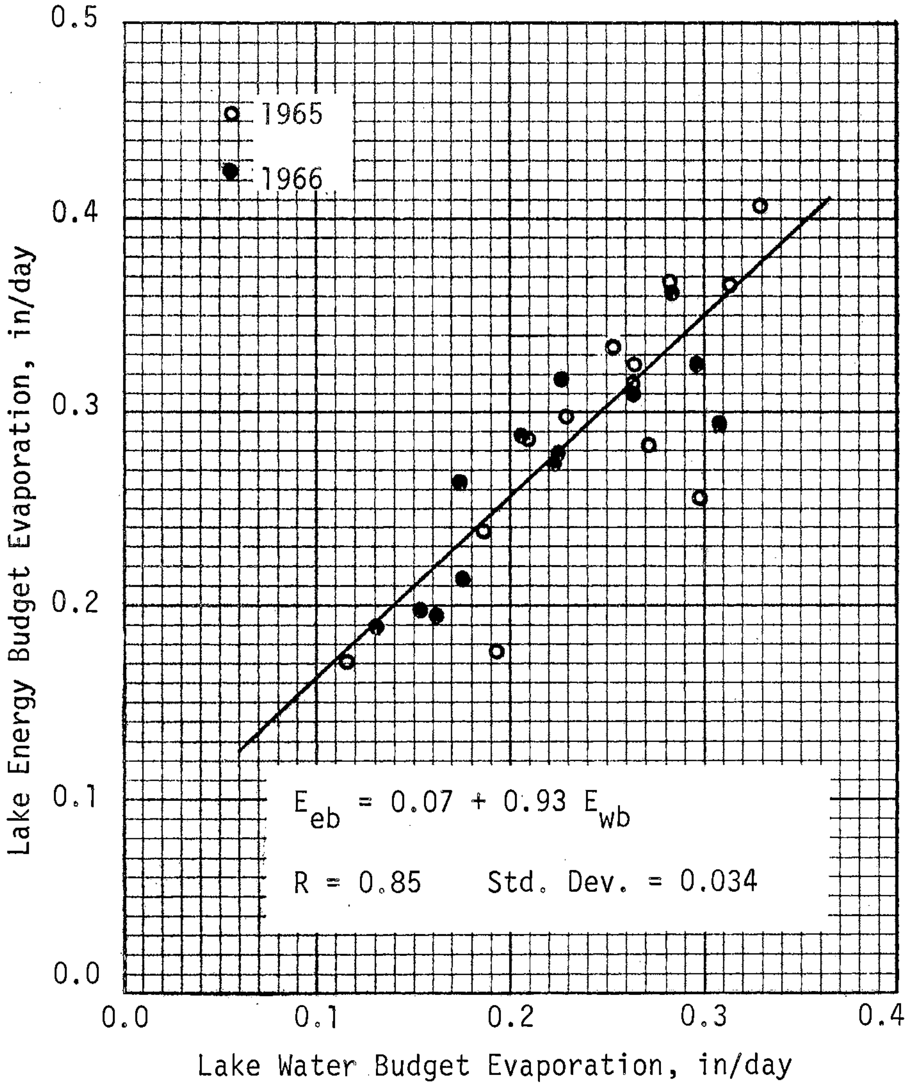

Figure 25. Relation Between Energy Budget Evaporation and Water Budget Evaporation at Lake Hefner, 1965 and 1966.

All instruments were calibrated at the beginning of the 1965 season. The Beckman and Whitley flat plate radiometer, which was the basic radiation instrument, was recalibrated at the factory before the start of each season. The similarity of the equations of best fit for 1965 and 1966 indicates that whatever caused the discrepancy between the water budget and energy budget was present during both years. It is possible that the discrepancy was caused by suspected errors in the factory calibration of the Beckman and Whitley flat plate radiometer, or possibly by the theoretical shortcomings of the Bowen ratio. A lengthy discussion of each term in the energy budget equation is included in Chapter VII.

Historical Comparison of Lake Hefner Water Budget Evaporation

Figure 26 shows a plot of cumulative lake water budget evaporation beginning on July 25 in each of the years of 1950 (50), 1958 (48), 1965, and 1966. This historical comparison indicates that there was fair general agreement in evaporation during the four years. It also shows that the effect of treating the lake with a monomolecular film cannot be determined by comparison of evaporation during treatment with that of past years, as climatic factors obviously overshadow the effects of treatment. For instance, the total cumulative evaporations during the periods of July 25 to September 26, 1950 and 1966, were almost identical yet in 1966 the lake was treated during 43 days of that 64-day period.

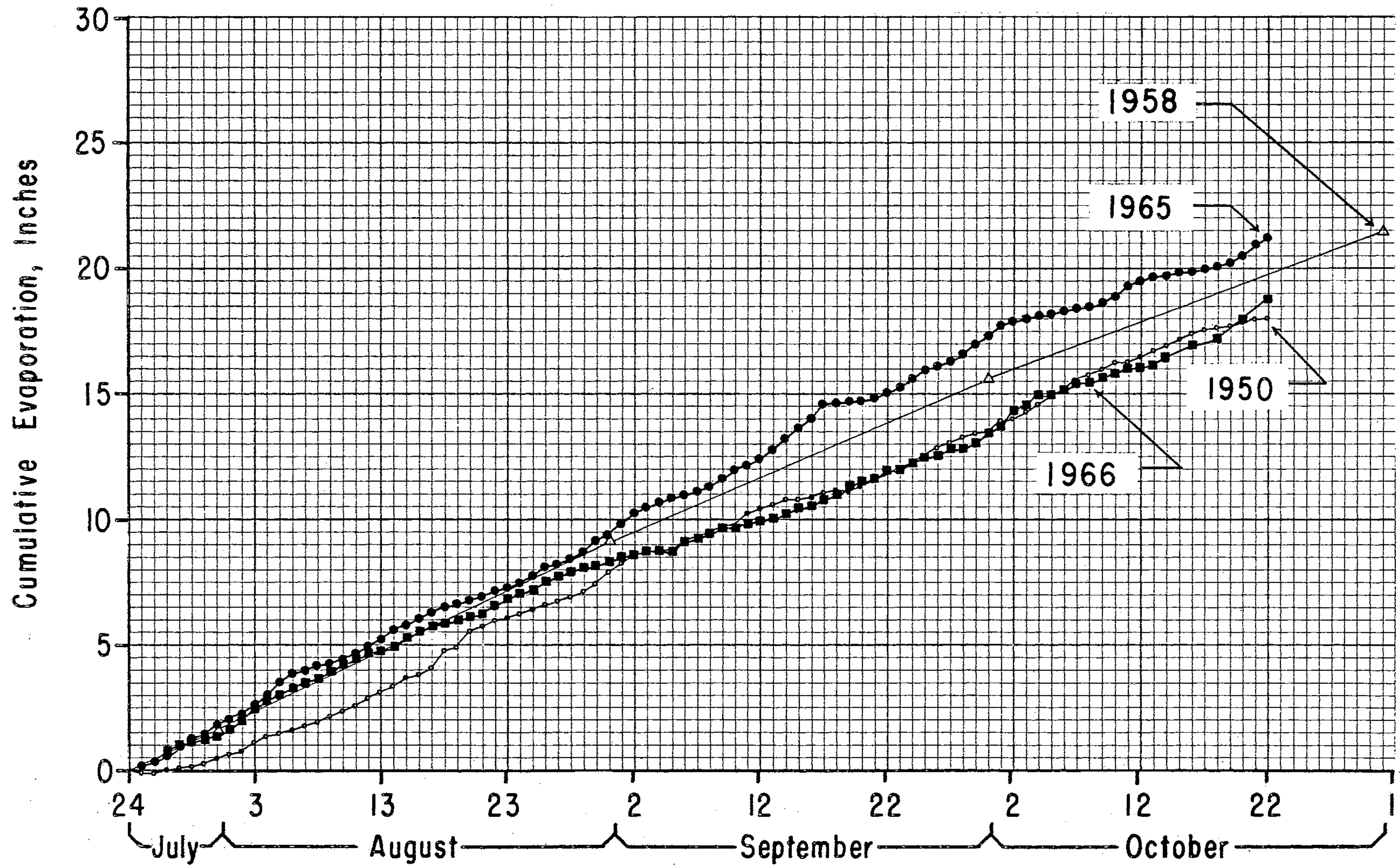

Figure 26. Comparison of Cumulative Evaporation from Lake Hefner During, 1950, 1958, 1965, and 1966.

CHAPTER IX

RESULTS OF THE PAN EVAPORATION REDUCTION STUDIES

Evaporation from Treated and Untreated Pans and Tanks

Appendix C lists evaporation rates and evaporation reductions for all pairs of treated and untreated pans and tanks during 1966. The treatment period extended from June 23 to December 4, 1966, a period of 164 days. The data for several days were omitted because of errors introduced into the record during heavy rains. These omissions are denoted in Appendix C by the remark, "Begin new treatment period".

Figures 27 through 30 show double mass curves of cumulative evaporation from the treated versus the untreated evaporation pans and tanks. The evaporation reductions during the study period common to all four pairs of pans and tanks (August 16 to December 4, 1966) are summarized in Table X.

TABLE X

EVAPORATION REDUCTIONS FROM TREATED PANS AND TANKS AT LAKE HEFNER

Type Pan or Tank 8/16/66-12/04/66	Evaporation Reduction
Class A Pan	63.3%
Sunken 4-Foot Tank	62.0%
Sunken Class A Pan	58.6%
Sunken 9-Foot Tank	44.5%

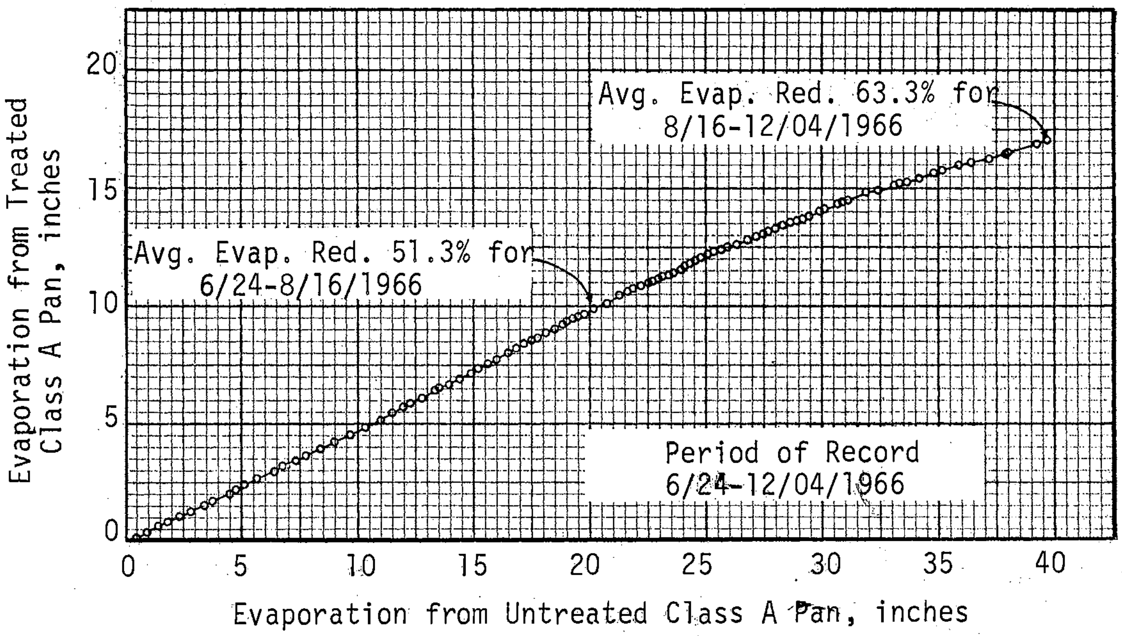

Figure 27. Comparison of Evaporation from the Treated and Untreated Class A Pans.

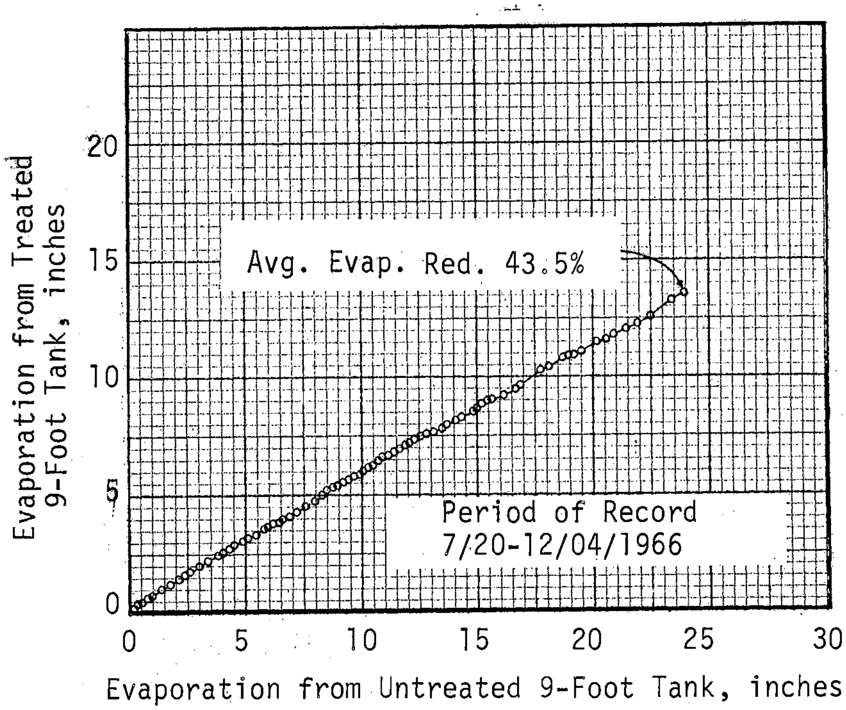

Figure 28. Comparison of Evaporation from the Treated and Untreated Sunken 9-Foot Tanks.

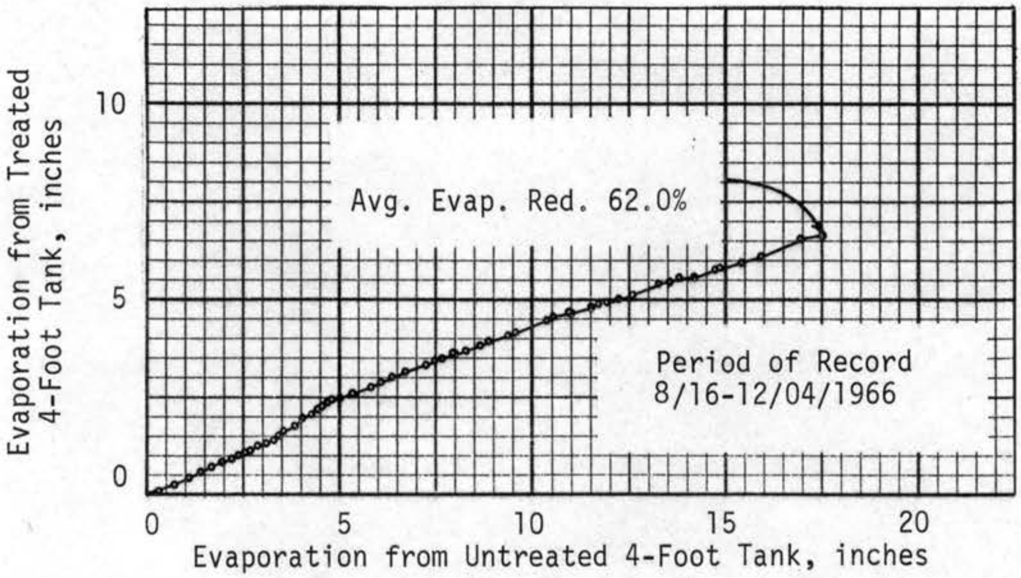

Figure 29. Comparison of Evaporation from the Treated and Untreated Sunken 4-Foot Tanks.

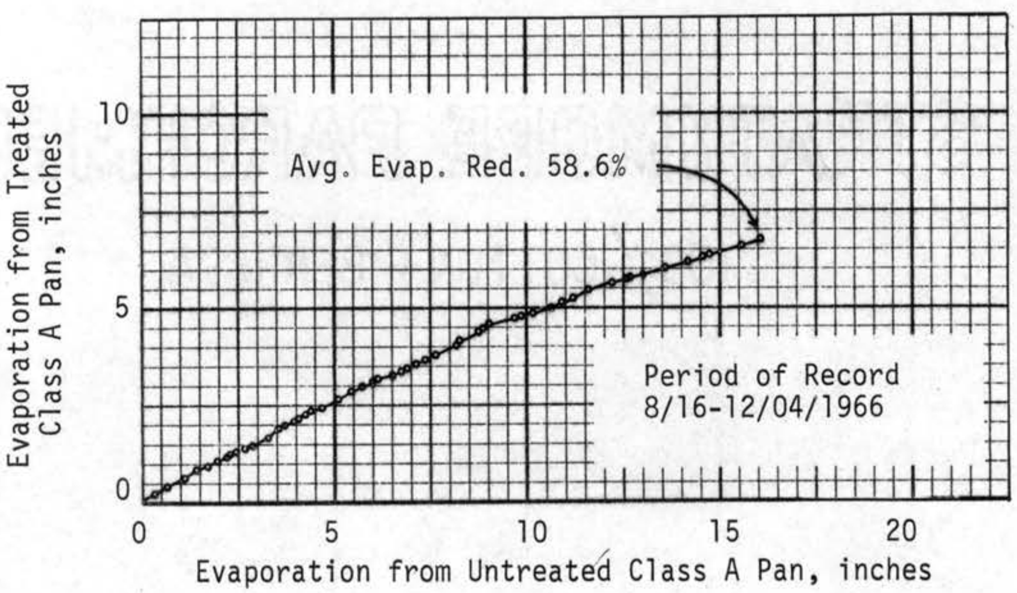

Figure 30. Comparison of Evaporation from the Treated and Untreated Sunken Class A Pans.

Setting the Class A pan into the ground had little effect on the evaporation reduction, but increasing the diameter of the sunken tank from 4 to 9 feet decreased the evaporation reduction from 62.0 to 44.5 percent. This decrease was caused by wind blowing the film cover to one side of the 9-foot tank and is discussed in a later section.

The evaporation reduction for all the 4-foot diameter pans and tanks was greater during the latter part of the season, reflecting the greater efficiency of the film at lower temperatures. For example, the Class A pan had average evaporation reductions of 63.3 and 51.3 percent during the periods of August 16 to December 4 and June 24 to August 16, 1966. The reduction for the 9-foot tank was essentially the same for all seasons, probably because of its more stable temperature.

The results of the brief 1965 pan evaporation study are not shown in the tables and graphs. The evaporation reduction for the Class A pans during the period of September 11 to October 23, 1965, was 57.5 percent.

Water Surface Temperatures

Appendix D lists the daily water surface temperatures for all treated and untreated pans and tanks, as well as the daily increases in temperature (ΔT) resulting from treatment. Figures 31 through 34 show this same data graphically. The average ΔT's and other pertinent quantities are summarized in Table XI.

ΔT changed relatively little as the season progressed. The increase in temperature persisted even during the cold weather of November and December. In order to test for a possible relationship between ΔT and the water surface temperature, linear regression equations were

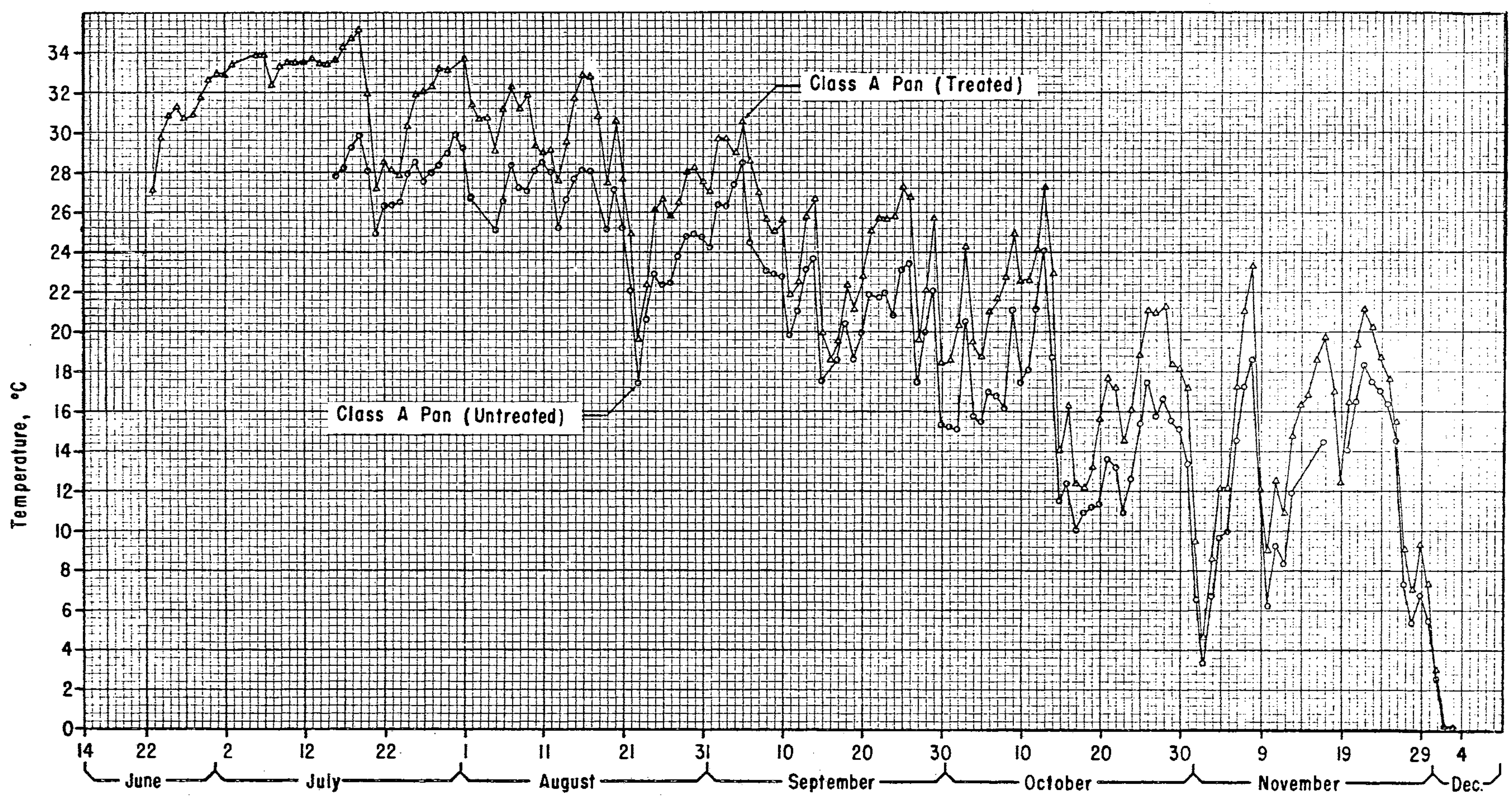

Figure 31. Seasonal Variation of Water Surface Temperatures of Class A Pans.

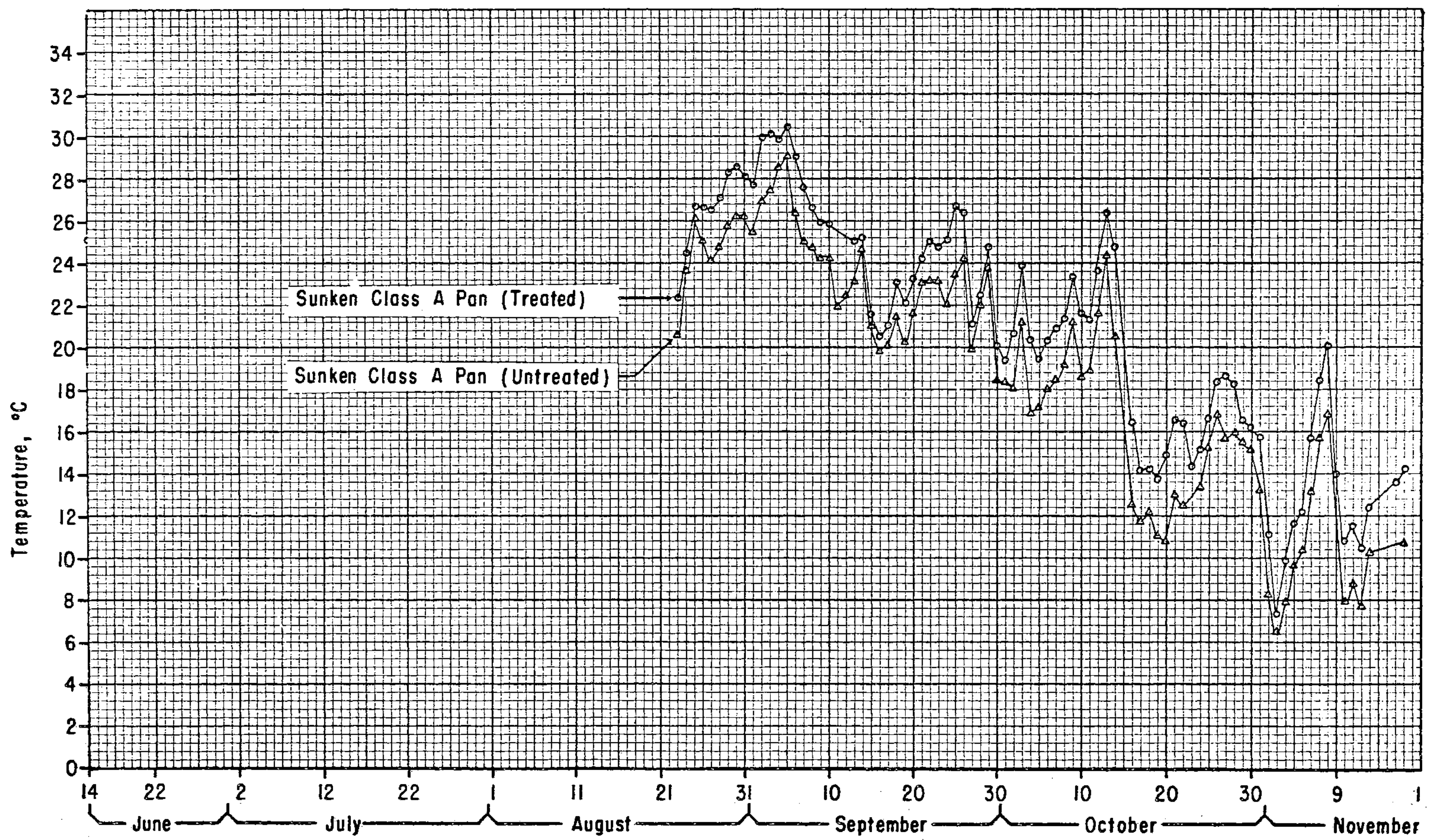

Figure 32. Seasonal Variation of Water Surface Temperatures of Sunken Class A Pans.

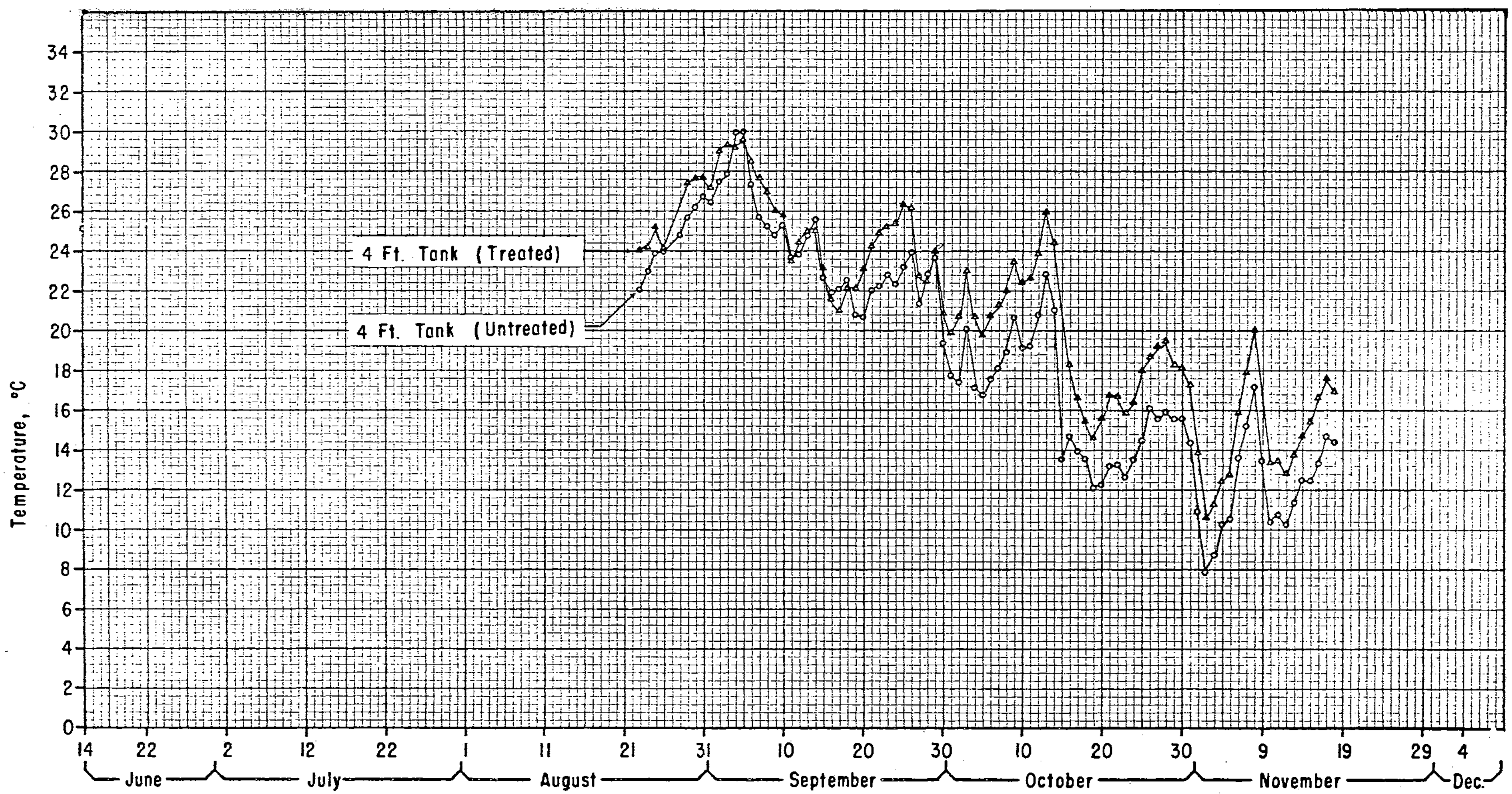

Figure 33. Seasonal Variation of Water Surface Temperatures of Sunken 4-Foot Tanks.

Figure 34. Seasonal Variation of Water Surface Temperatures of Sunken 9-Foot Tanks.

TABLE XI

INCREASE IN PAN WATER SURFACE TEMPERATURES CAUSED BY MONOMOLECULAR FILM

Type Pan Or Tank	Period of Observation 1966	Average Increase in Water Surface Temperature, ΔT °C	Maximum ΔT °C	Date	Minimum ΔT °C	Date
Class A	7/16-12/03	3.14	6.67	10/08	0.06[a]	12/02
Sunken Class A	8/23-11/17	2.14	4.22	10/14	0.50	9/28
Sunken 4-Foot Tank	8/23-11/18	2.19	3.72	10/27	-0.94[b]	9/17
Sunken 9-Foot Tank	7/21-12/03	2.85	4.72	9/08	0.61	11/27

(a) Pans frozen during part of the day
(b) Rain

developed for all four pairs of pans and tanks. Only the regression equations for the Class A pan and 9-foot tank were significant at the 0.05 confidence level or better:

Class A pan

$$\Delta T = 0.36 + 0.078\ T \tag{46}$$

$$R = 0.43^{**}$$

9-foot tank

$$\Delta T = 2.47 + 0.04\ T \tag{47}$$

$$R = 0.35^{**}$$

where

ΔT = increase in water surface temperature, °F

T = water surface temperature of treated tank, °F

In general the temperatures of all treated pans and tanks were usually greater than the 2-meter air temperature, with the exception of a few warm days in November. During most of the season the average daily temperature of the untreated Class A pan was about the same as the average daily 2-meter air temperature.

Diurnal Variation of Water Surface Temperatures

Figure 35 shows the diurnal variation in water surface temperatures for the Class A pans, the 9-foot tanks, and the 15-foot tank for November 22, 1966. The variations shown are typical of those during the entire study period of June to December, although they are not as extreme as those occurring in mid-summer. The daily minimum and

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One asterisk (*) indicates significance at the 0.05 confidence level, and two asterisks (**) indicate significance at the 0.01 confidence level.

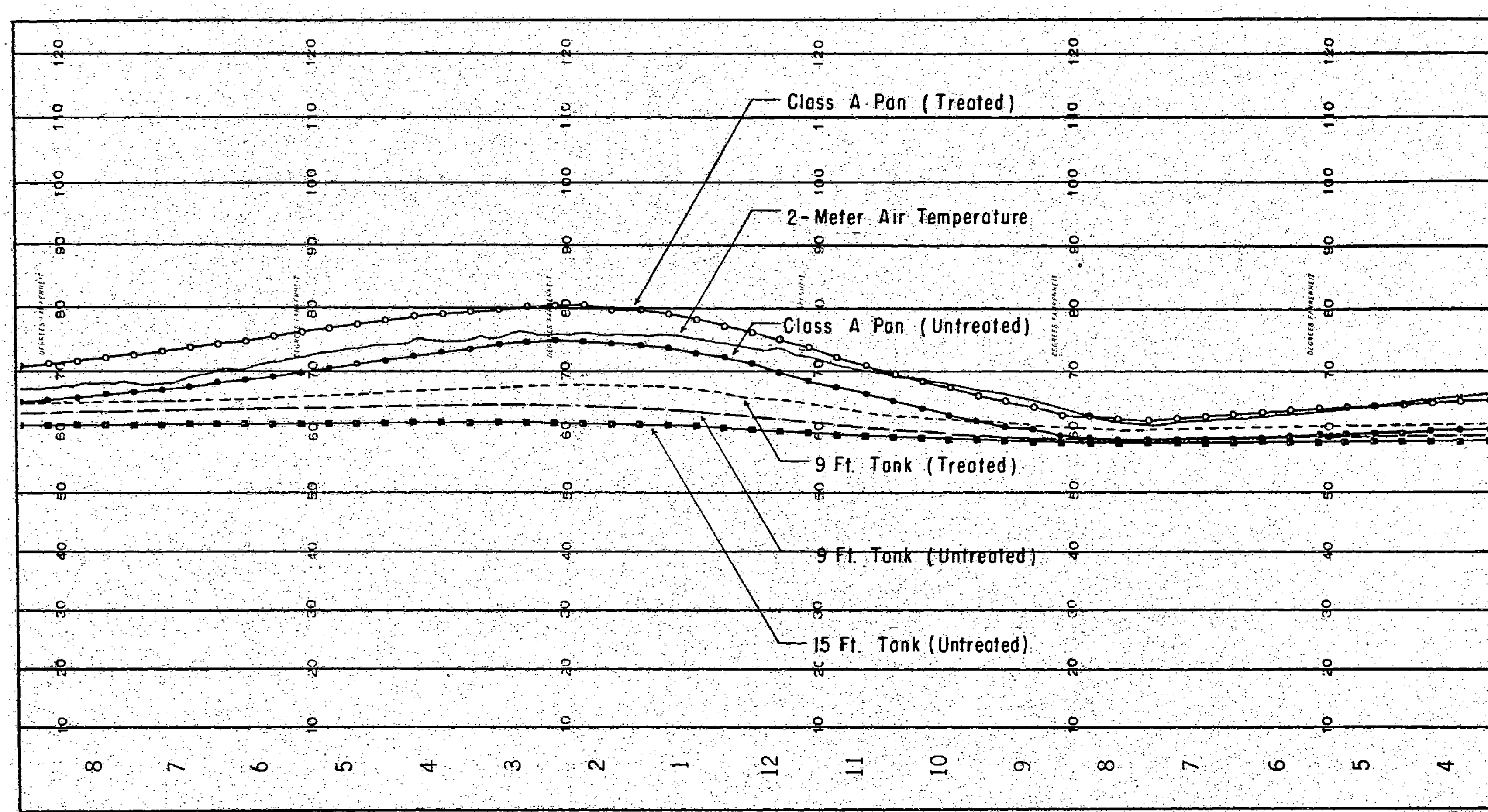


Figure 35. Diurnal Variation of Pan and Tank Water Surface Temperatures on November 22, 1966.

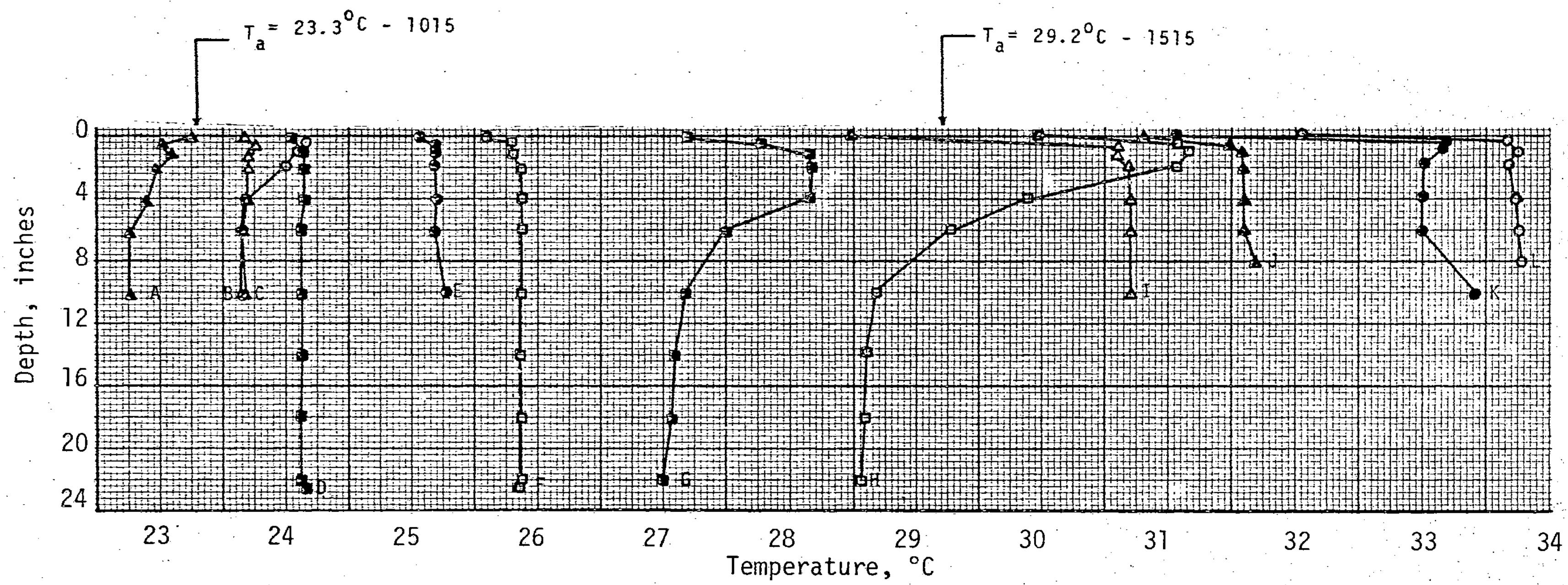
maximum temperatures usually occurred at sunrise and at 1430, respectively. On rainy days the diurnal variations were small, primarily because the low incoming radiation did not provide enough energy to increase the water temperature.

Water Temperature Profiles

Figures 36 and 37 show the water temperature profiles for all treated and untreated pans and tanks at 1015 and 1515 on August 31, 1966. The temperatures were measured with a calibrated Atkins resistance thermometer utilizing a thermistor bead 1/8-inch in diameter. The standard Class A pan had a greater increase in temperature between 1015 and 1515 than any of the sunken pans or tanks. The temperature increase in the treated pans and tanks existed throughout the profile and remained fairly constant during this particular day.

The profiles at 1515 have a water surface temperature as much as 2.5°C cooler than the temperature at the 0.5-inch depth. These sharp temperature decreases near the water surface are in agreement with the laboratory study of Jarvis (25).

The lake temperature profile at 1515 is shown in Figure 37. Although sharp temperature gradients existed in the upper few inches of the relatively sheltered evaporation pans, the temperature profile of the untreated lake at 1515 apparently was vertical throughout the upper five feet. The exact shape of the lake temperature profile is unknown because measurements were taken only at 1/2 inch, 2.5 feet, and 5 feet. However, any temperature gradient existing in the upper few inches of the lake had probably been destroyed by turbulence.



A Untreated Class A Pan - 1015
B Untreated Sunken Class A Pan - 1015
C Treated Class A Pan - 1015
D Untreated 4-Foot Tank - 1015
E Treated Sunken Class A Pan - 1015
F Treated 4-Foot Tank - 1015
G Untreated 4-Foot Tank - 1515
H Treated 4-Foot Tank - 1515
I Untreated Sunken Class A Pan - 1515
J Untreated Class A Pan - 1515
K Treated Sunken Class A Pan - 1515
L Treated Class A Pan - 1515

Figure 36. Temperature Profiles of Pans and Tanks at South Station - August 31, 1966.

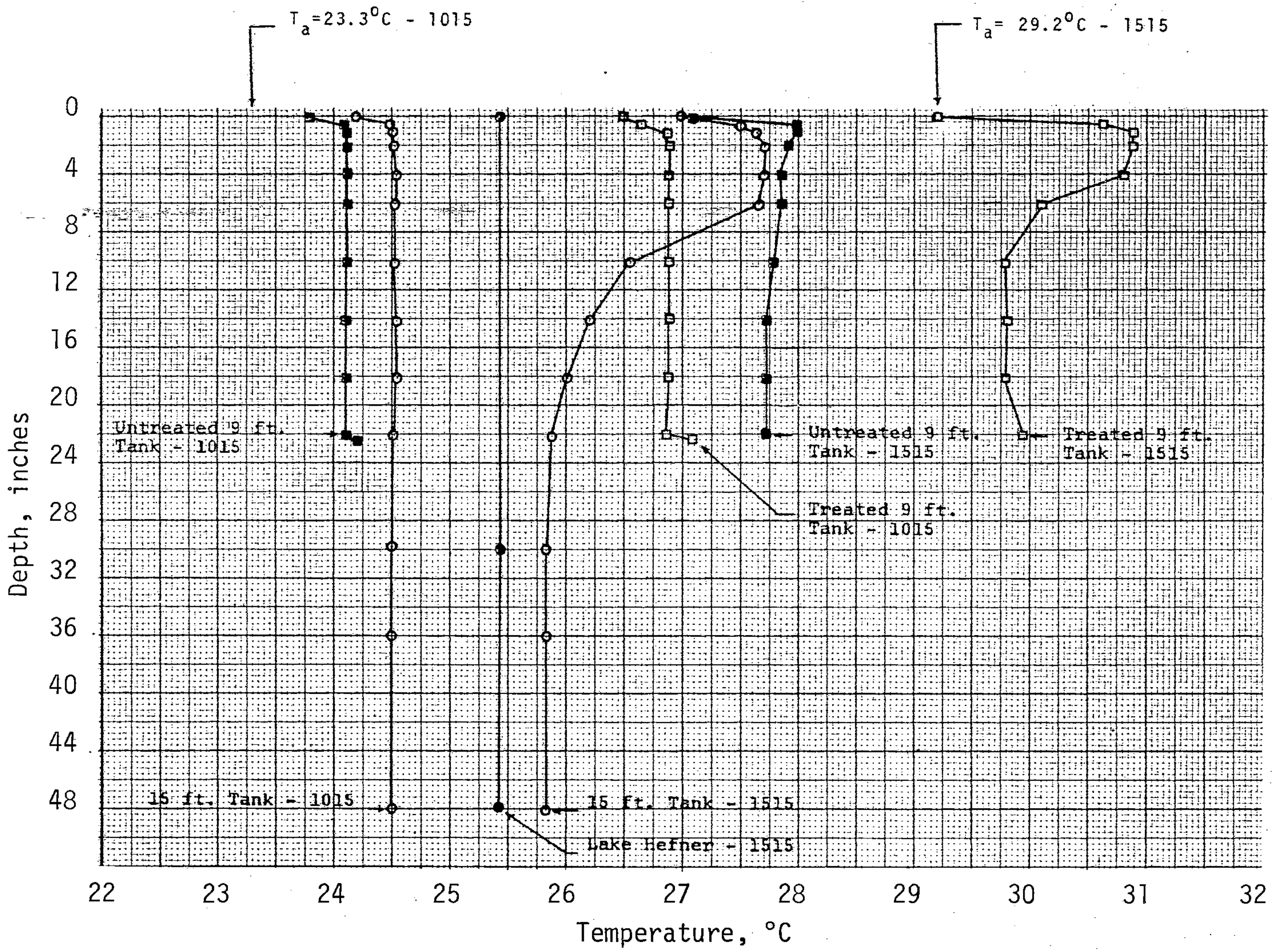


Figure 37. Temperature Profiles of Sunken Tanks at South Station--August 31, 1966.

Evaporation Reduction as a Function of Water Surface Temperature

Figure 38 shows the relationships between the evaporation reduction factor F and the water surface temperature T for the four pairs of treated and untreated evaporation pans and tanks. The regression equations listed in the order of their evaporation reductions are:

Class A pan

$$F = 115.89 - 0.72\ T \tag{48}$$

$R = -0.83^{**}$ Std. Dev. = 6.3

Sunken 4-foot tank

$$F = 125.49 - 0.88\ T \tag{49}$$

$R = -0.64^{**}$ Std. Dev. = 9.6

Sunken Class A pan

$$F = 126.88 - 0.97\ T \tag{50}$$

$R = -0.63^{**}$ Std. Dev. = 12.4

Sunken 9-foot tank

$$F = 80.66 - 0.42\ T \tag{51}$$

$R = -0.32^{**}$ Std. Dev. = 14.88

An analysis of covariance indicated that all of the regression lines were statistically different from each other at the 0.05 confidence level, with one exception. The difference between the standard Class A pan and the sunken 4-foot tank was not significant, even at the 0.10 level.

The evaporation reduction for the sunken Class A pan was less than that for the standard Class A pan for an undetermined reason. The low evaporation reduction for the 9-foot tank was caused by the wind blowing the film to one side of the tank.

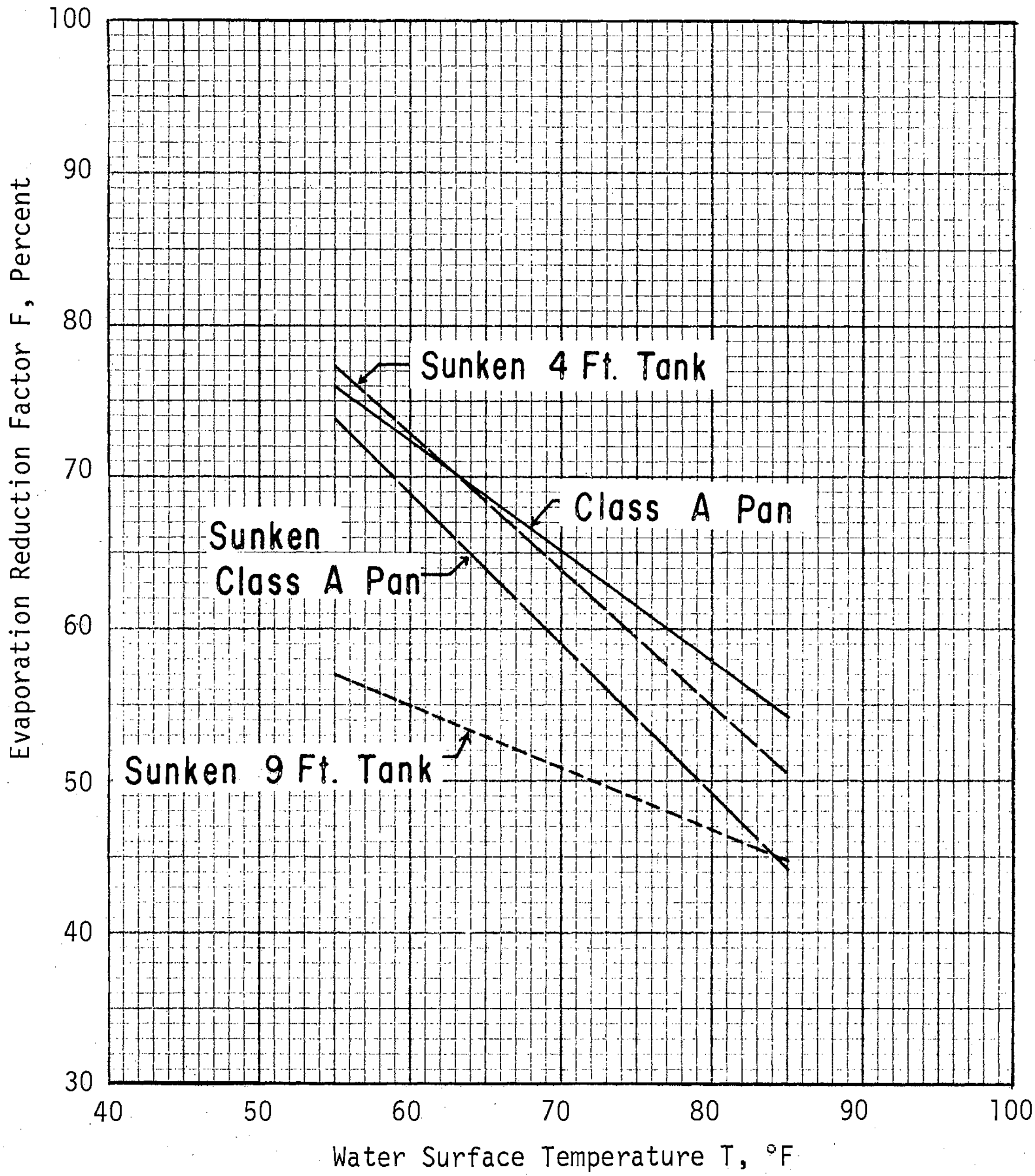


Figure 38. Evaporation Reduction Resulting from Application of Monomolecular Films to Evaporation Pans and Tanks.

Evaporation Reduction as a Function of Wind Speed

The linear regression equation expressing the evaporation reduction for the 9-foot tank as a function of 2-meter south station wind speed is:

$$F = 66.7 - 2.06\ u_{ss-2} \qquad (52)$$

$$R = -0.53^{**} \qquad \text{Std. Dev.} = 13.4$$

Equation 52 is based on wind speeds ranging from 2 to 21 miles per hour. The average wind speed during the period of study was 8.13 miles per hour. The good correlation between evaporation reduction and wind speed for Equation 52 suggests that the monomolecular film on the 9-foot tank must have been blown to one side by the wind during a significant portion of the time. This effect can be seen in Figure 39, which shows excess film blown to the leeward side of the tank. The correlation between evaporation reduction and wind speed was not meaningful for any of the other pans or tanks.

In order to more adequately evaluate the effect of both wind speed and water surface temperature on evaporation reduction, the following linear and cubic multivariate regression equations were derived:

Class A pan (linear)

$$F = 114.65 - 0.71\ T + 0.09\ u_{ss-2} \qquad (53)$$

$$R = 0.83^{**}$$

Sunken Class A pan (linear)

$$F = 115.69 - 0.91\ T + 0.87\ u_{ss-2} \qquad (54)$$

$$R = 0.66^{**}$$

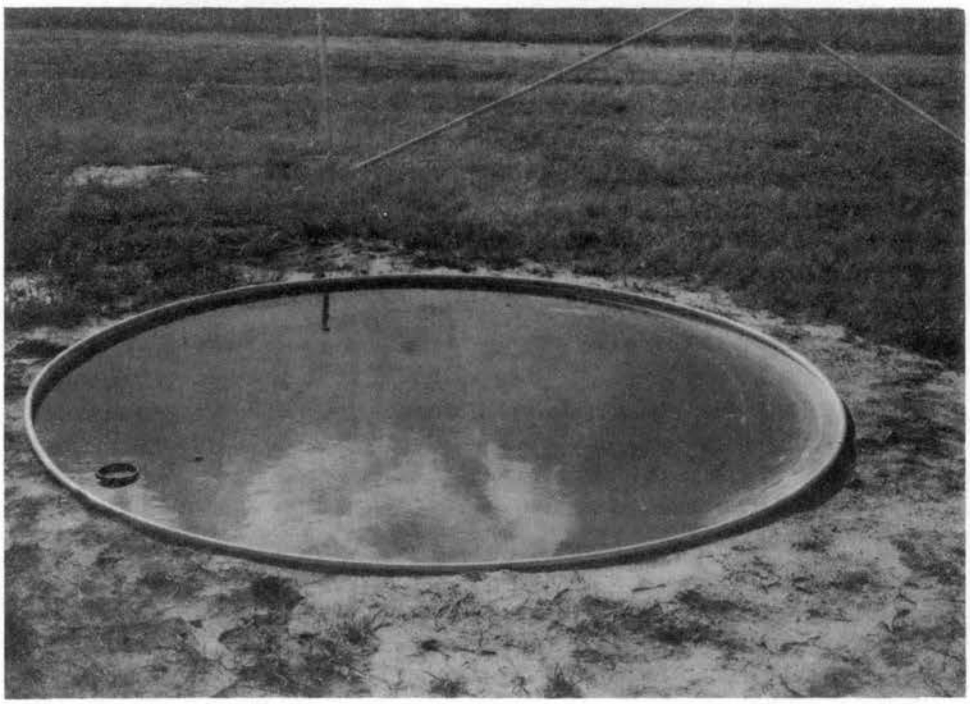


Figure 39. Treated 9-Foot Diameter Sunken Tank. The wind has blown excess film to the right side of tank.

Sunken 9-foot tank (linear)

$$F = 117.87 - 0.65\ T - 2.55\ u_{ss-2} \qquad (55)$$

$$R = 0.71^{**}$$

Sunken 9-foot tank (cubic)

$$F = -48.68 + 6.77\ T - 0.1086\ T^2 + 0.00047\ T^3 \qquad (56)$$

$$-2.62\ u_{ss-2} - 0.5492\ (u_{ss-2})^2 + 0.01269\ (u_{ss-2})^3$$

$$+0.0951\ Tu_{ss-2}$$

$$R = 0.79^{**}$$

The inclusion of wind speed in the linear and cubic multivariate equations for the 9-foot tank gave a considerable improvement in the correlation coefficient over that of Equation 51. The three dimensional plot of the cubic response surface is shown in Figure 40. The damaging effect of high winds on evaporation reduction is evident.

A comparison of Equations 48, 50, 53, and 54 shows that the inclusion of the wind speed in the linear miltivariate equations for both the standard and sunken Class A pans had little effect on the correlation coefficients. Equations 48 and 50 are similar to Equations 53 and 54 when the wind speed is zero. Likewise, Equation 48 for the Class A pan is similar to Equation 55 for the 9-foot tank when the wind speed is zero. This similarity suggests that the evaporation reduction for a Class A pan at various nonzero wind speeds was approximately the same as that of a 9-foot tank at zero wind speed.

Evaporation Reduction as a Function of Surface Area

The results of the 1965-1966 Lake Hefner evaporation suppression study and of the associated pan evaporation studies, plus the published results of previous lake evaporation studies, provide a means of

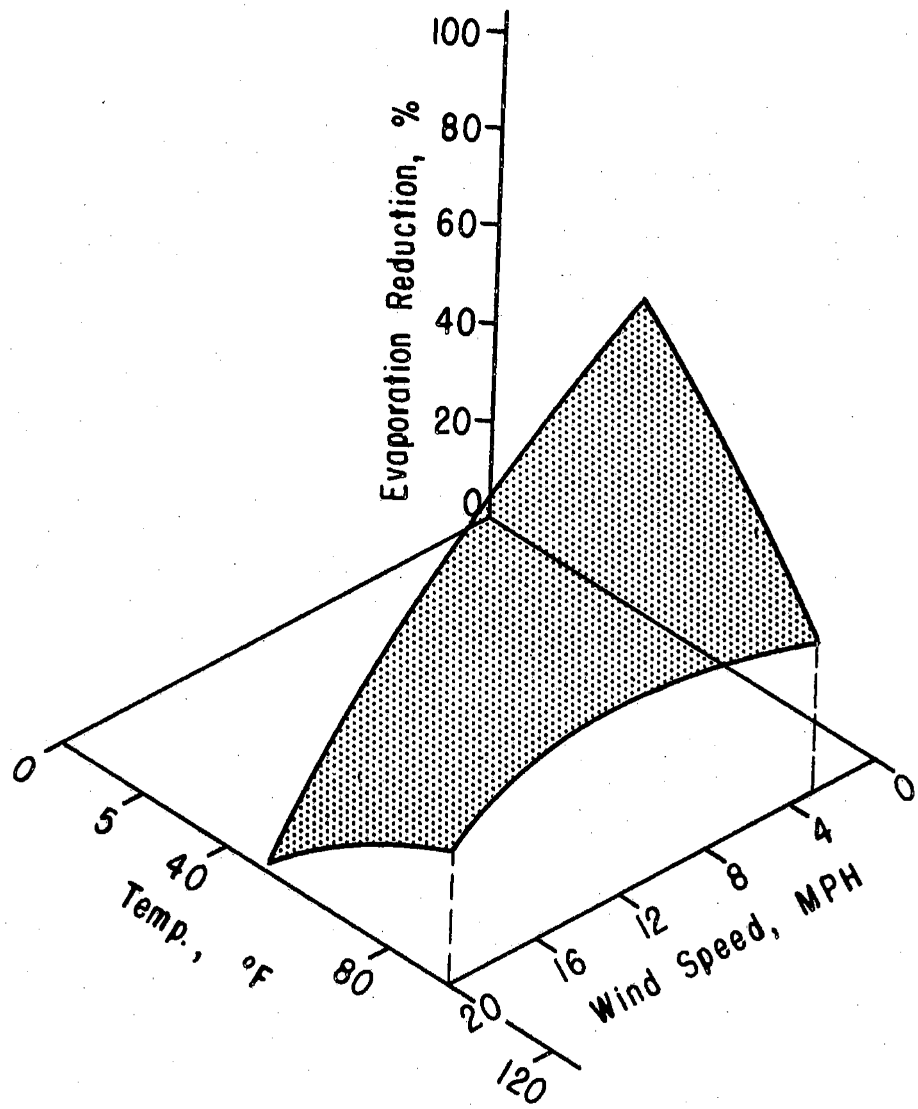


Figure 40. Response Surface Expressing Evaporation Reduction for the 9-Foot Tank as a Cubic Function of Temperature and Wind Speed.

evaluating evaporation reduction as a function of the surface area of the body of water. Figure 41 is a log-log plot of evaporation reduction versus surface area, using data from various sizes of lakes, ponds, and sunken tanks and pans. The areas of the various bodies of water ranged from 12.57 square feet for a sunken Class A pan to 134,000,000 square feet (3090 acres) for Lake Cachuma. The evaporation reductions ranged from a high of 62 percent for the sunken Class A pan to a low of 8 percent for Lake Cachuma. The data plotted in the figure fall almost in a straight line. The equation of the line of best fit is:

$$ER = 62.5\,A^{-0.092} \tag{57}$$

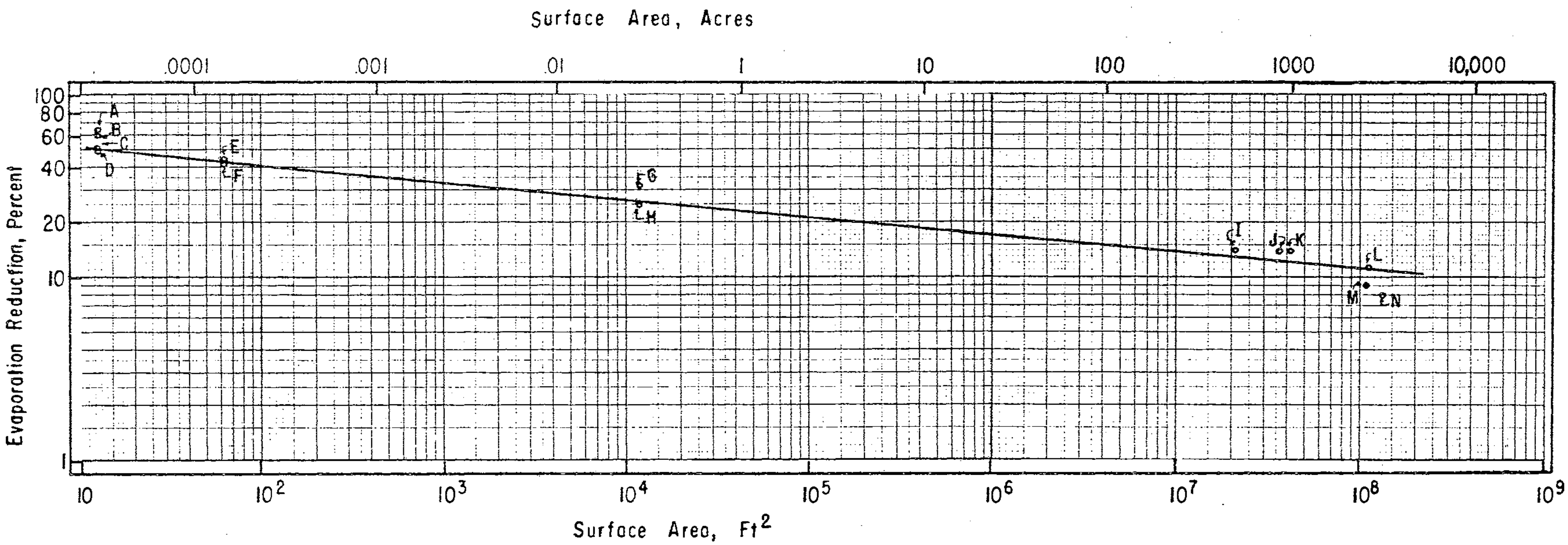
where

ER = evaporation reduction, percent

A = surface area, ft^2

The data making up Figure 41 were the results of a number of different investigations using differing application rates, times of application, mixtures of alcohol, and methods of application. Considering these differences, the consistency of the data is good. This suggests that, at the present state of the art, the evaporation reduction that can be achieved on lakes larger than Lake Hefner may be around 11 percent or less. The combined effects of wind and wave action on the film, plus the physical limitations of application equipment, present barriers to high evaporation reduction on large lakes.

However, all of the reservoirs shown in Figure 41 are located in the western United States in regions of moderate to high prevailing wind speeds. The evaporation reduction would probably be higher in an



A	Sunken 4-Foot Tank 8/16-12/04	1966	
B	Sunken Class A Pan 8/16-12/04	1966	
C	Sunken 4-Foot Tank 8/16-9/15	1966	
D	Sunken Class A Pan 8/16-9/15	1966	
E	Sunken 9-Foot Tank 7/20-12/04	1966	
F	Sunken 9-Foot Tank 7/20-9/15	1966	
G	Stillwater Pond 8/14-10/05	1966	
H	Stillwater Pond July-October	1959	
I	Pactola Reservoir 8/25-9/07	1962	
J	Pactola Reservoir 7/5-10/09	1963	
K	Sahuaro Lake 10/01-11/17	1960	
L	Lake Hefner Sept.	1965	
	July-Sept.	1966	
M	Lake Hefner July-Sept.	1958	
N	Lake Cachuma 7/31-9/24	1961	

Figure 41. Evaporation Reduction as a Function of Water Surface Area.

area having lower wind speeds. Also, it is possible that future improvements in the monolayer-forming chemicals may improve the film efficiency.

CHAPTER X

RESULTS OF THE LAKE/TANK EVAPORATION STUDIES

Tables XII and XIII list the total evaporation by TSP's for the Lake Hefner water budget, 15-foot and 9-foot tanks, Stillwater pond, Class A pan, and CRI. The daily evaporation from the same bodies of water is given in Appendix E.

The average lake/pond evaporation ratio was 1.03 for 10 untreated TSP's in 1965 and 1.17 for 8 untreated TSP's in 1966. Lake evaporation exceeded pond evaporation during 12 of the 18 TSP's.

The average lake/tank ratio for both the 15-foot and 9-foot tanks was 1.01 for 13 untreated TSP's in 1966. Although the average lake/tank ratio was close to unity, there was a marked seasonal variation in the ratio. The lake/tank ratio varied more for the 9-foot tank than the 15-foot tank.

The average lake/pan ratios for the Class A pan and the CRI were 0.77 and 0.78, respectively, during 19 untreated TSP's in 1965 and 1966. In general, the evaporation rates for the Class A pan and CRI were in close agreement.

Comparison of Evaporation from Lake Hefner and the Stillwater Pond

Figures 42 and 43 show the cumulative evaporation from Lake Hefner and the Stillwater pond for 1965 and 1966. The cumulative 15-foot tank evaporation is also shown in Figure 43 for reference in the next section.

TABLE XII

1965 SUMMARY OF EVAPORATION FROM LAKE, POND, CLASS A PAN, AND CRI BY THERMAL SURVEY PERIODS

		Lake Hefner Water Budget			Stillwater Pond			Class A Pan			CRI		
TSP	Dates 1965	Total in	Daily in/day	Cum in	Total in	Daily in/day	Lake/Pond Ratio	Total in	Daily in/day	Lake/Pond Ratio	Total in	Daily in/day	Lake/CRI Ratio
1	June 03-June 10	0.92	0.135	0.92							2.36	0.346	
2	June 10-June 17	-0.18	-0.026	0.74				2.26	0.323		2.54	0.362	
3	June 17-June 24	3.00	0.429	3.74				2.59	0.367		2.49	0.354	
4	June 24-July 01	2.42	0.345	6.16				2.72	0.390	0.891	2.78	0.398	0.870
5	July 01-July 08	1.85	0.265	8.01				2.71	0.388	0.681	2.63	0.374	0.703
6	July 08-July 15	1.98	0.283	9.99				3.05	0.433	0.650	3.19	0.457	0.620
7	July 15-July 22	2.30	0.329	12.29				3.53	0.504	0.652	3.30	0.472	0.697
8	July 22-July 29	1.90	0.273	14.19	2.04	0.292	0.931	2.81	0.399	0.676			
9	July 29-Aug 05	2.20	0.313	16.39	2.19	0.312	1.005	2.66	0.382	0.826	2.55	0.362	0.863
10	Aug 09-Aug 16(a)	1.60	0.230	17.99	2.02	0.289	0.792	2.16	0.307	0.739	2.24	0.323	0.714
11	Aug 16-Aug 23	1.44	0.209	19.43	1.65	0.240	0.873				2.21	0.323	0.652
12	Aug 23-Aug 31	2.03	0.253	21.46	2.66	0.333	0.763	3.24	0.464	0.626	3.39	0.425	0.599
13	Sept 01-Sept 06	1.31	0.264	22.77	1.05	0.211	1.248	1.66	0.328	0.791	1.56	0.311	0.840
14	Sept 06-Sept 10(b)	0.73	0.186	23.50	1.01	0.254	0.723				1.45	0.362	
15	Sept 10-Sept 16	2.15	0.347	25.65	1.82	0.293	1.181	2.76	0.442	0.778	2.39	0.386	0.900
16	Sept 24-Oct 02	2.31	0.295	27.96	1.33	0.170	1.737	1.51	0.192	1.529	1.55	0.197	1.490
17	Oct 02-Oct 10	0.93	0.118	28.89	0.94	0.118	0.989	1.15	0.146	0.805	1.08	0.138	0.861
18	Oct 10-Oct 23	2.51	0.192	31.40	2.23	0.171	1.126	2.74	0.209	0.917	2.80	0.213	0.896
Totals (TSP's 8-13, 15-18)(c)		18.38			17.93	Avg. =	1.025						
Totals (TSP's 4-10, 12-13, 15-18)(d)		25.49						32.69	Avg. =	0.777			
Totals (TSP's 4-7, 9-10, 12-13, 15-18)(e)		23.59						29.88	Avg. =	0.789	29.46	Avg. =	0.801

(a) The following dates were omitted from record: August 5-9, August 31-September 1, and September 16-24, 1965.

(b) The lake was treated with a monomolecular film during this TSP.

(c) Totals exclude TSP's that were treated or that had missing pond data.

(d) Totals exclude TSP's with missing pan data.

(e) Totals exclude TSP's with missing CRI or pan data.

TABLE XIII

1966 SUMMARY OF EVAPORATION FROM LAKE, POND, TANKS, CLASS A PAN, AND CRI BY THERMAL SURVEY PERIODS

		Lake Hefner Water Budget			15-Foot Tank			9-Foot Tank			Stillwater Pond			Class A Pan			CRI		
TSP	Dates 1966	Total in	Daily in/day	Cum in	Total in	Daily in/day	Lake/Tank Ratio	Total in	Daily in/day	Lake/Tank Ratio	Total in	Daily in/day	Lake/Pond Ratio	Total in	Daily in/day	Lake/Pan Ratio	Total in	Daily in/day	Lake/CRI Ratio
1	June 14-June 21	1.44	0.207	1.44															
2	June 21-June 28	1.98	0.282	3.42										3.32	0.472	0.596	3.00	0.429	0.660
3	June 28-July 06	1.83	0.226	5.25										4.05	0.499	0.451	3.66	0.453	0.500
4	July 06-July 12	1.82(c)	0.309	7.07	2.58	0.438	0.705	2.48	0.420	0.734				3.28	0.556	0.554	2.90	0.492	0.628
5	July 12-July 25(a)	6.20	0.474	13.27	4.24	0.324	1.462	4.30	0.329	1.442							4.90	0.374	
6	July 25-Aug 02	1.81(c)	0.223	15.08	2.29	0.283	0.790	2.52	0.311	0.718	2.63	0.325	0.688				3.62	0.449	0.500
7	Aug 03-Aug 10(b)	1.87(c)	0.264	16.95	2.12	0.299	0.882	2.01	0.284	0.930	1.70	0.240	1.100				2.41	0.339	0.776
8	Aug 12-Aug 19	1.27(c)	0.177	18.22	1.86	0.259	0.683	2.06	0.287	0.617	1.59	0.221	0.799						
9	Aug 19-Aug 28	1.98	0.226	20.20	1.71	0.195	1.158	1.69	0.193	1.171	1.76	0.201	1.125				2.04	0.232	0.971
10	Aug 28-Sept 03	0.84(c)	0.132	21.04	0.94	0.147	0.894	1.08	0.169	0.778	0.74	0.116	1.135				1.46	0.228	0.575
11	Sept 04-Sept 12	1.23(c)	0.154	22.27	1.42	0.178	0.866	1.72	0.216	0.715	1.30	0.163	0.946	1.44	0.180	0.854	1.57	0.197	0.783
12	Sept 12-Sept 21	1.44	0.161	23.71	1.04	0.116	1.385	0.93	0.104	1.548	1.32	0.147	1.091				1.60	0.177	0.900
13	Sept 21-Sept 29	1.40	0.175	25.11	1.33	0.167	1.053	1.42	0.178	0.986	1.30	0.163	1.077				1.79	0.224	0.782
14	Sept 29-Oct 06	2.07	0.297	27.18	1.39	0.199	1.489	1.35	0.193	1.533	1.44	0.206	1.438	1.48	0.212	1.398	1.61	0.232	1.286
15	Oct 06-Oct 15	1.67	0.189	28.85	1.90	0.215	0.879	2.00	0.226	0.835	1.93	0.218	0.865	2.43	0.274	0.687	2.45	0.276	0.682
16	Oct 15-Oct 22	1.91	0.273	30.76	1.16	0.166	1.647	1.11	0.159	1.721	1.19	0.170	1.605				1.07	0.149	1.785
17	Oct 22-Oct 29	0.84	0.120	31.60	0.85	0.121	0.988	0.93	0.133	0.903	0.83	0.119	1.012	1.22	0.174	0.688	1.34	0.191	0.627
18	Oct 29-Nov 05	1.29	0.184	32.89	1.01	0.144	1.277	0.97	0.139	1.330	1.02	0.146	1.265	0.99	0.141	1.303	1.10	0.157	1.173
19	Nov 05-Nov 12	0.75	0.107	33.64	0.94	0.134	0.798	0.98	0.140	0.765				1.35	0.192	0.555			
20	Nov 12-Nov 19	0.69	0.099	34.33	0.87	0.124	0.793	0.94	0.134	0.734				1.42	0.202	0.485			
21	Nov 19-Nov 27	1.07	0.134	35.40	0.79	0.099	1.354	0.93	0.116	1.151				1.31	0.163	0.816			
22	Nov 27-Dec 04	1.40	0.200	36.80	0.76	0.109	1.842	0.57	0.081	2.456				0.53	0.075	2.641			
Totals (TSP's 9, 12-18)(d)		12.60			10.39	Avg. =	1.213	10.40	Avg. =	1.212	10.79	Avg. =	1.168				13.00	Avg. =	0.969
Totals (TSP's 4, 9, 12-22)(e)		16.51			16.33	Avg. =	1.011	16.30	Avg. =	1.013									
Totals (TSP's 2-3, 14-15, 17-22)(f)		13.59												18.10	Avg. =	0.751			
Totals (TSP's 2-3, 14-15, 17-18)(g)		9.68												13.49	Avg. =	0.718	13.16	Avg. =	0.736

(a) Accuracy of water budget questionable because of high inflow.
(b) The following dates were omitted from record: August 2-3 and August 10-12, 1966.
(c) The lake was treated with a monomolecular film during TSP's 4, 6, 7, 8, 10, and 11.
(d) Totals exclude TSP's that were treated or that had missing pond data.
(e) Totals exclude treated TSP's.
(f) Totals exclude TSP's with missing pan data.
(g) Totals exclude TSP's with missing CRI or pan data.

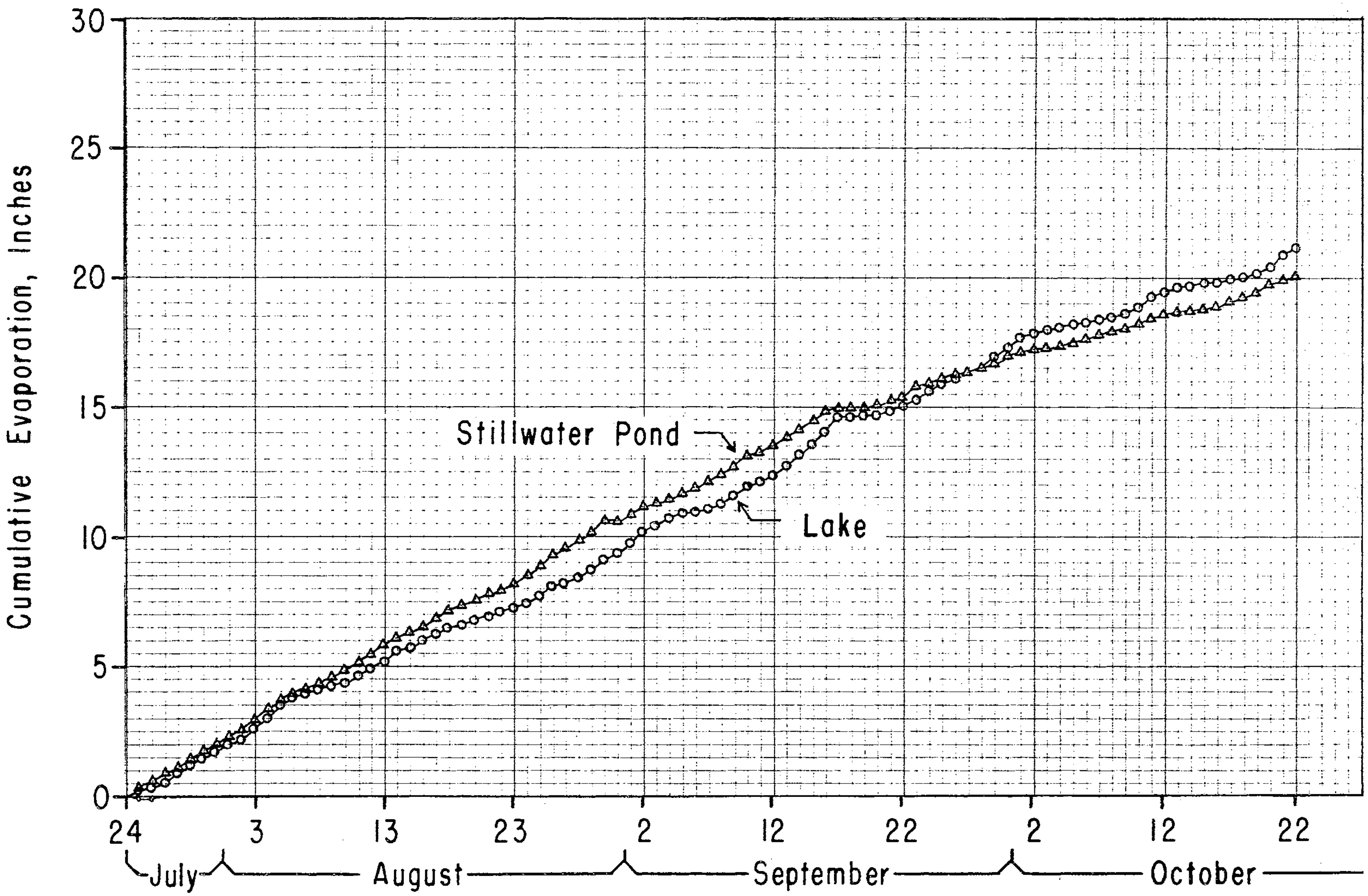


Figure 42. Cumulative Evaporation from Lake Hefner and Stillwater Pond During 1965.

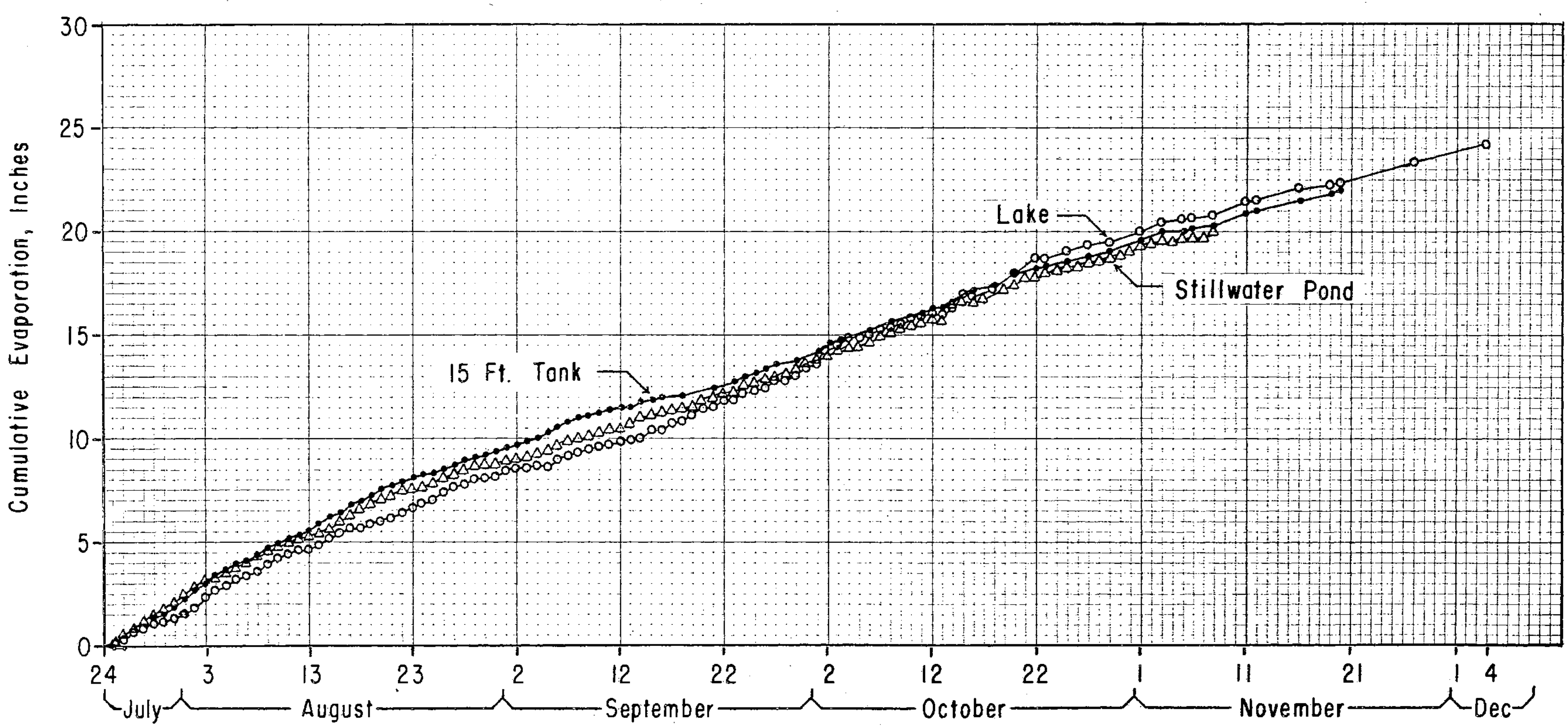


Figure 43. Cumulative Evaporation from Lake Hefner, 15-Foot Tank, and Stillwater Pond During 1966.

During the period of July 25 to October 23, 1965, the lake evaporation was 21.19 inches and the pond evaporation was 20.05 inches, a difference of 5.4 percent. For the same period in 1966, the lake evaporation was 18.89 inches compared with 17.94 inches from the pond, a difference of 4.5 percent. The most important feature shown in Figures 42 and 43 is that the cumulative pond evaporation exceeded the cumulative lake evaporation during the early part of the season, but after the last week of September, the reverse was true. This reversal of the respective evaporation rates was a seasonal effect caused by the more rapid cooling of the pond than the lake during the late summer and fall.

Figure 44 is a double mass plot of pond evaporation versus lake evaporation for the periods of July 24 to October 23, 1965, and July 25 to November 8, 1966. The seasonal shift is denoted in Figure 44 by the upward curvature of the two double mass lines. The agreement between 1965 and 1966 is good, considering the fact that the lake was treated with a monomolecular film during 43 days of the 106-day period in 1966. This close agreement between 1965 and 1966 indicates that the evaporation reduction during the treated period may have been small. It also suggests that the seasonal shift may be consistent from year to year, even though the pond and lake are 60 miles apart.

Although the double mass lines in Figure 44 approach a 1:1 line, the seasonal shift prevents the use of pond evaporation for other than a rough estimate of lake evaporation for short periods of time. This is shown by Figure 45, which is a plot of lake evaporation versus pond evaporation for 18 untreated TSP's in 1965 and 1966. The linear regression equation for lake evaporation as a function of pond evaporation is:

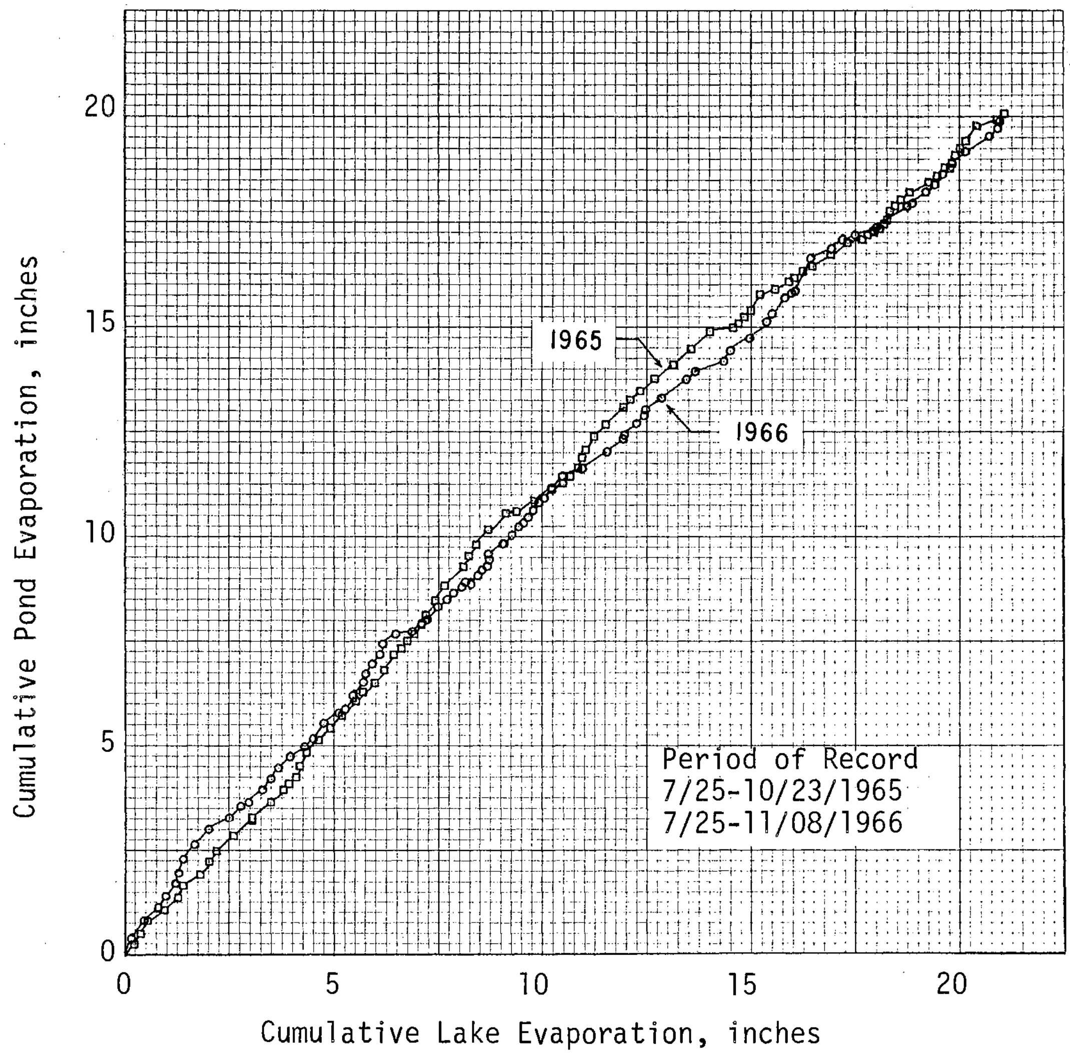


Figure 44. Double Mass Curves Comparing Pond Evaporation with Lake Evaporation During 1965 and 1966.

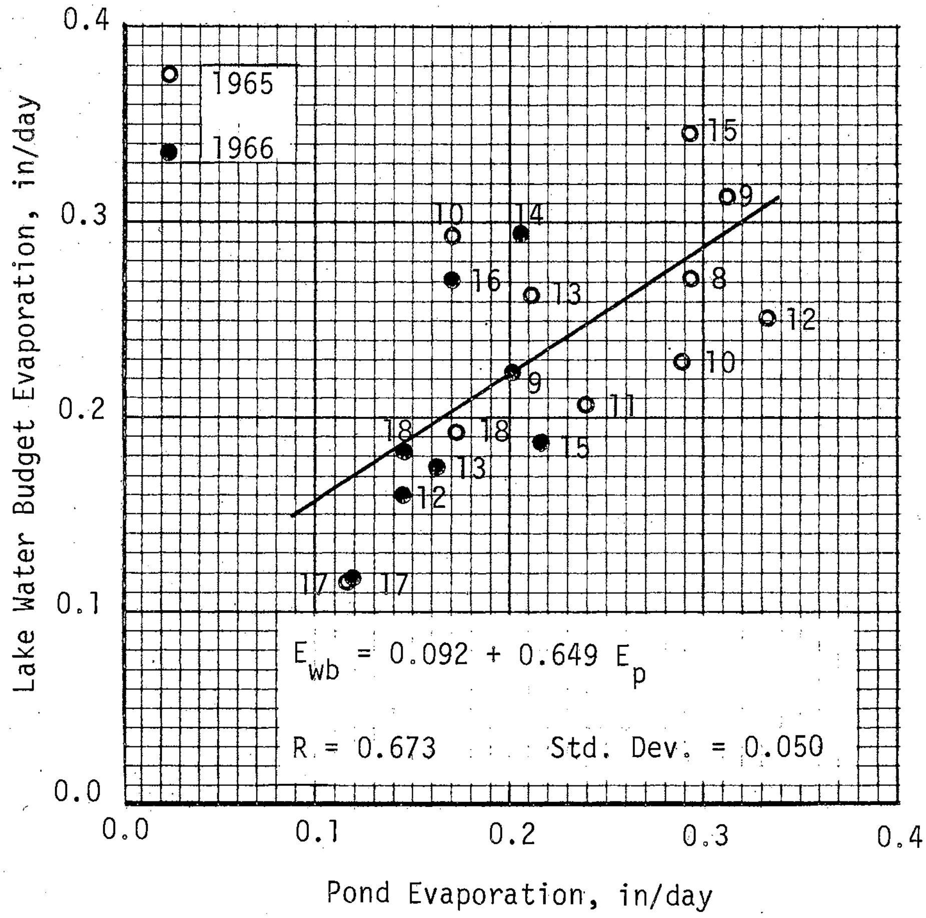


Figure 45. Lake Evaporation as a Function of Pond Evaporation. Thermal survey periods are identified by numerals.

$$E_{wb} = 0.092 + 0.649\ E_p \tag{58}$$

$$R = 0.67^{**} \qquad \text{Std. Dev.} = 0.05$$

The scatter of the data was caused in part by the seasonal shift in the relative evaporation rates of the lake and the pond.

Comparison of Evaporation from Lake Hefner and the 15-Foot Tank

Figure 42 shows the cumulative evaporation from the sunken 15-foot tank for the period of July 25 to December 4, 1966. Figure 46 is the double mass plot of pond and 15-foot tank evaporation versus lake evaporation for the periods of July 25 to November 8 and July 25 to December 4, 1966, respectively. The seasonal shift in evaporation rates relative to the lake was greater for the 15-foot tank than for the pond because of the smaller heat capacity of the tank.

Figure 47 shows the linear regression of lake evaporation as a function of 15-foot tank evaporation for 13 untreated TSP's in 1966. The equation of the regression line is:

$$E_{wb} = 0.096 + 0.548\ E_{15} \tag{59}$$

$$R = 0.69^{**} \qquad \text{Std. Dev.} = 0.052$$

Equation 59 is similar to Equation 58. If the difference in location is ignored, apparently the 15-foot sunken tank provided as good an estimate of lake evaporation as did the 0.28-acre Stillwater pond.

A linear regression of daily lake evaporation on daily 15-foot tank evaporation was not satisfactory because of the phase difference between the times of measurements, and because of occasional large errors in daily lake evaporation caused by the effect of wind on the

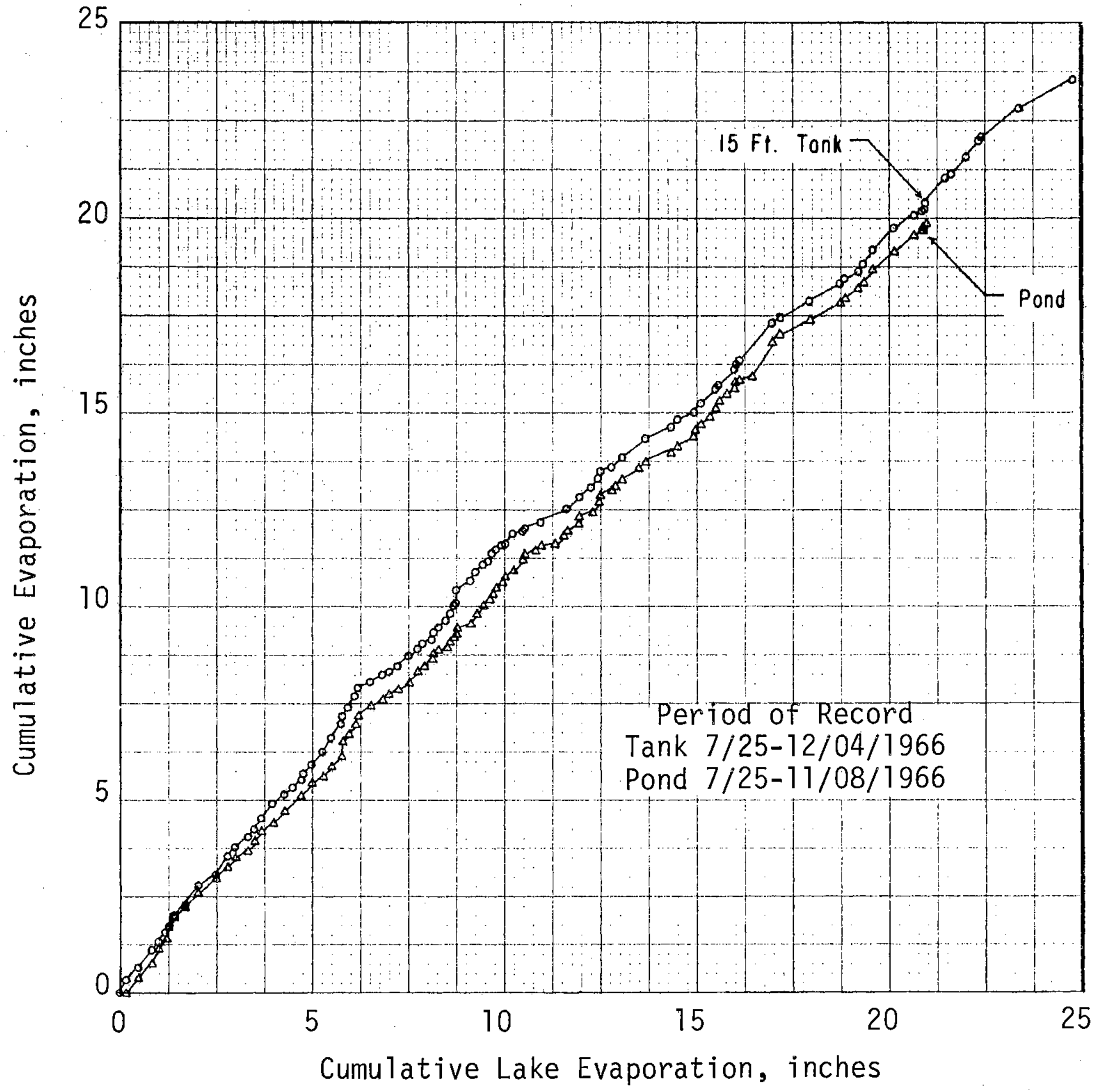


Figure 46. Double Mass Curves Comparing Lake Evaporation with Evaporation from 15-Foot Tank and from Stillwater Pond.

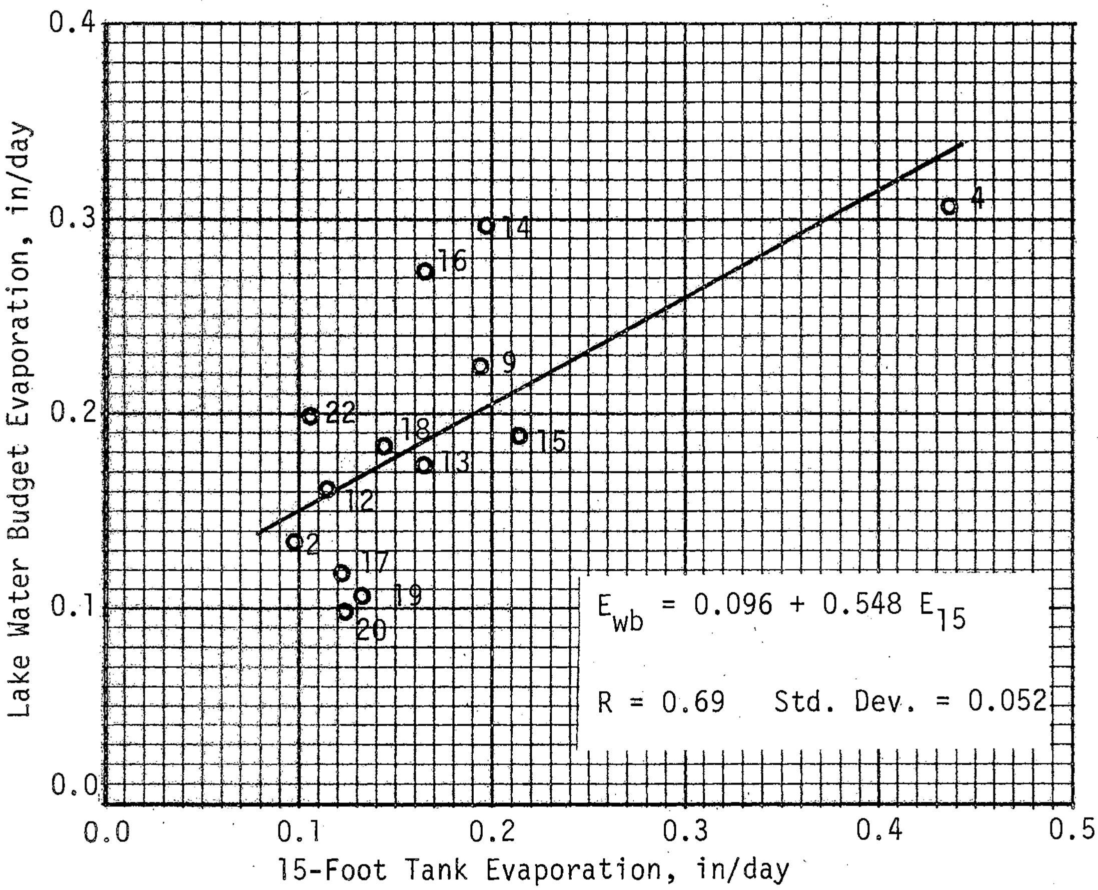


Figure 47. Lake Evaporation as a Function of 15-Foot Tank Evaporation.

lake stage. Fortunately, such errors caused by wind effects were not cumulative, and thus had little effect on the lake evaporation over periods of several days.

Comparison of Evaporation from the 15-Foot and 9-Foot Sunken Tanks

Figure 48 is a double mass plot of evaporation from the 15-foot tank versus that from the 9-foot tank and Stillwater pond. The relationship between the evaporation from the two sunken tanks is nearly linear. For the period of July 25 to December 4, 1966, the total evaporation from the 15-foot tank was 23.49 inches compared with 24.44 inches from the 9-foot tank, a difference of only 3.1 percent.

Figure 49 shows the linear regression of 9-foot tank evaporation as a function of 15-foot tank evaporation for 17 TSP's in 1966. The good fit of the linear regression line indicates the potential accuracy of direct comparisons of evaporation when the bodies of water are adjacent to each other.

Comparison of Evaporation from the 15-Foot Tank and the Stillwater Pond

The double mass curve in Figure 48 shows that the cumulative pond evaporation of 19.80 inches was slightly less than the cumulative 15-foot tank evaporation of 20.37 inches for the period of July 25 to November 8, 1966. The difference in evaporation of 0.57 inch or 2.8 percent over a period of 106 days was quite small, considering the 60-mile distance between the pond and the tank.

The close agreement between the evaporation from the two bodies of water is further demonstrated in Figure 50, which shows the linear

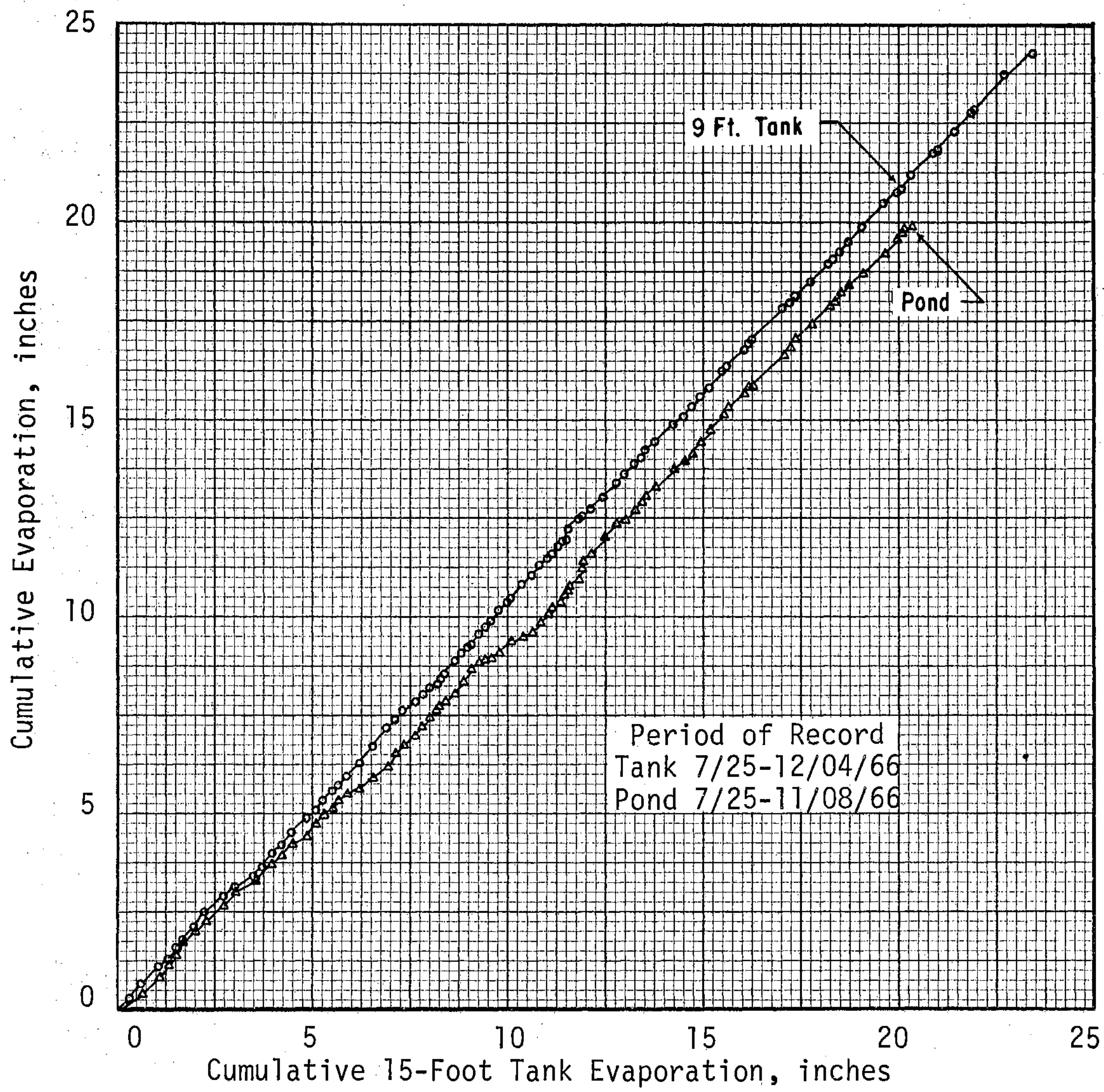


Figure 48. Double Mass Curves Comparing 15-Foot Tank Evaporation with Evaporation from 9-Foot Tank and from Stillwater Pond.

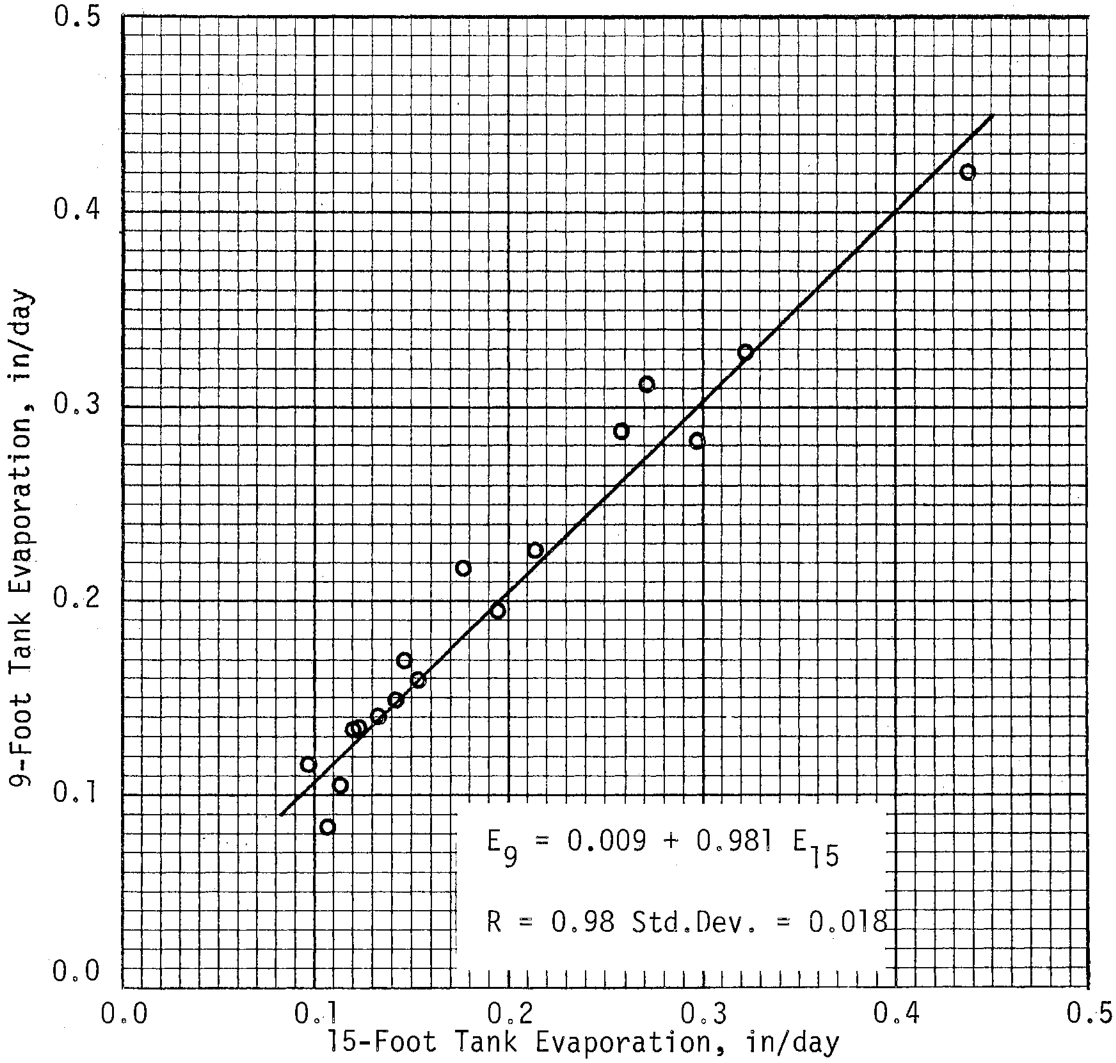


Figure 49. Relationship Between 9-Foot Tank Evaporation and 15-Foot Tank Evaporation.

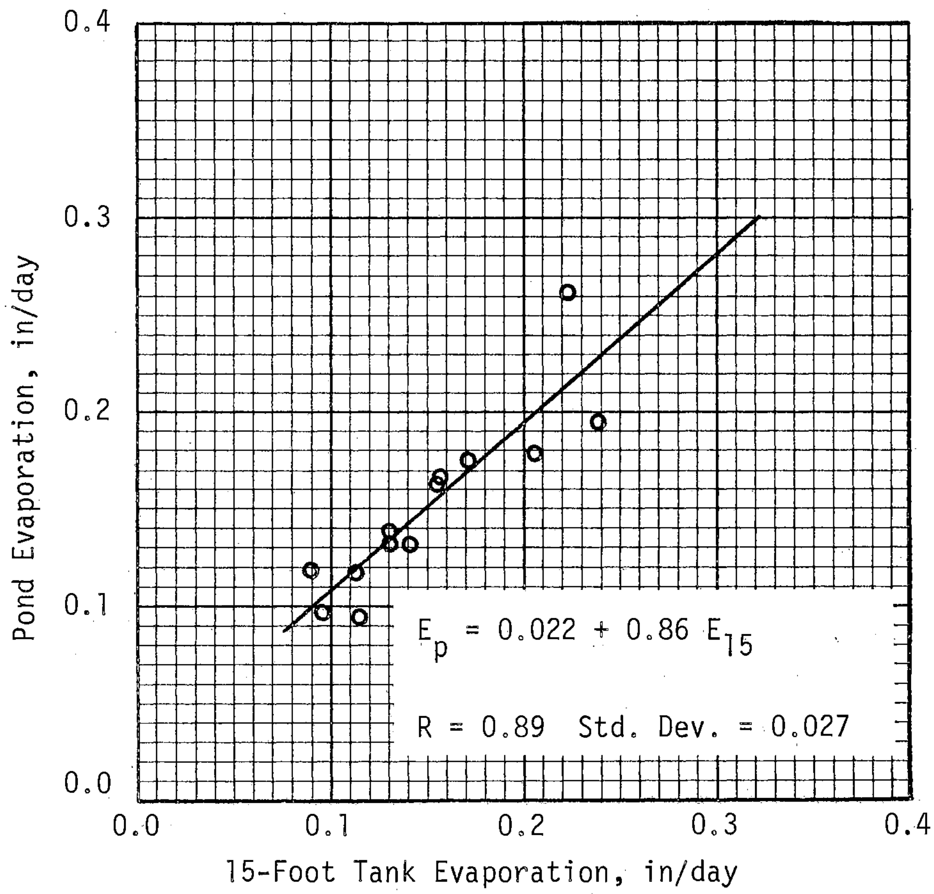


Figure 50. Pond Evaporation as a Function of 15-Foot Tank Evaporation.

regression of pond evaporation as a function of 15-foot tank evaporation for 13 TSP's in 1966. The correlation was significant at the 0.001 level.

Water Surface Temperature, Air Temperature, and Relative Humidity

Figure 51 shows the daily water surface temperatures of Lake Hefner and the 15-foot sunken tank, and Figure 52 shows the 2-meter air temperature and relative humidity at the south station. The highs and lows of the water surface temperature of the 15-foot tank closely followed those of the 2-meter air temperature, although the amplitudes of the fluctuations for the tank were smaller. Both the lake and the tank had generally declining water surface temperatures after August 1. During the period August 1 to December 4, 1966, the surface temperature of the lake was generally higher than that of the tank, except during periods of high solar radiation. The daily record of the water surface temperature of the 9-foot tank, shown in Figure 34, was similar to that of the 15-foot tank.

Table XIV is a summary by TSP's of the temperature, psychrometric, and evaporation data used in the development of the lake evaporation prediction equation. The period of interest originally included TSP's 6 to 22. However, during TSP 19 the thermocouple psychrometer at the south station was disconnected and the relative humidity for TSP's 19 to 22 was obtained from the United States Weather Bureau observations at Will Rogers Airport located about 10 miles south of the lake. These data were later found to be unreliable for use in development of the lake prediction equation because of the difference between the microclimates of the two locations.

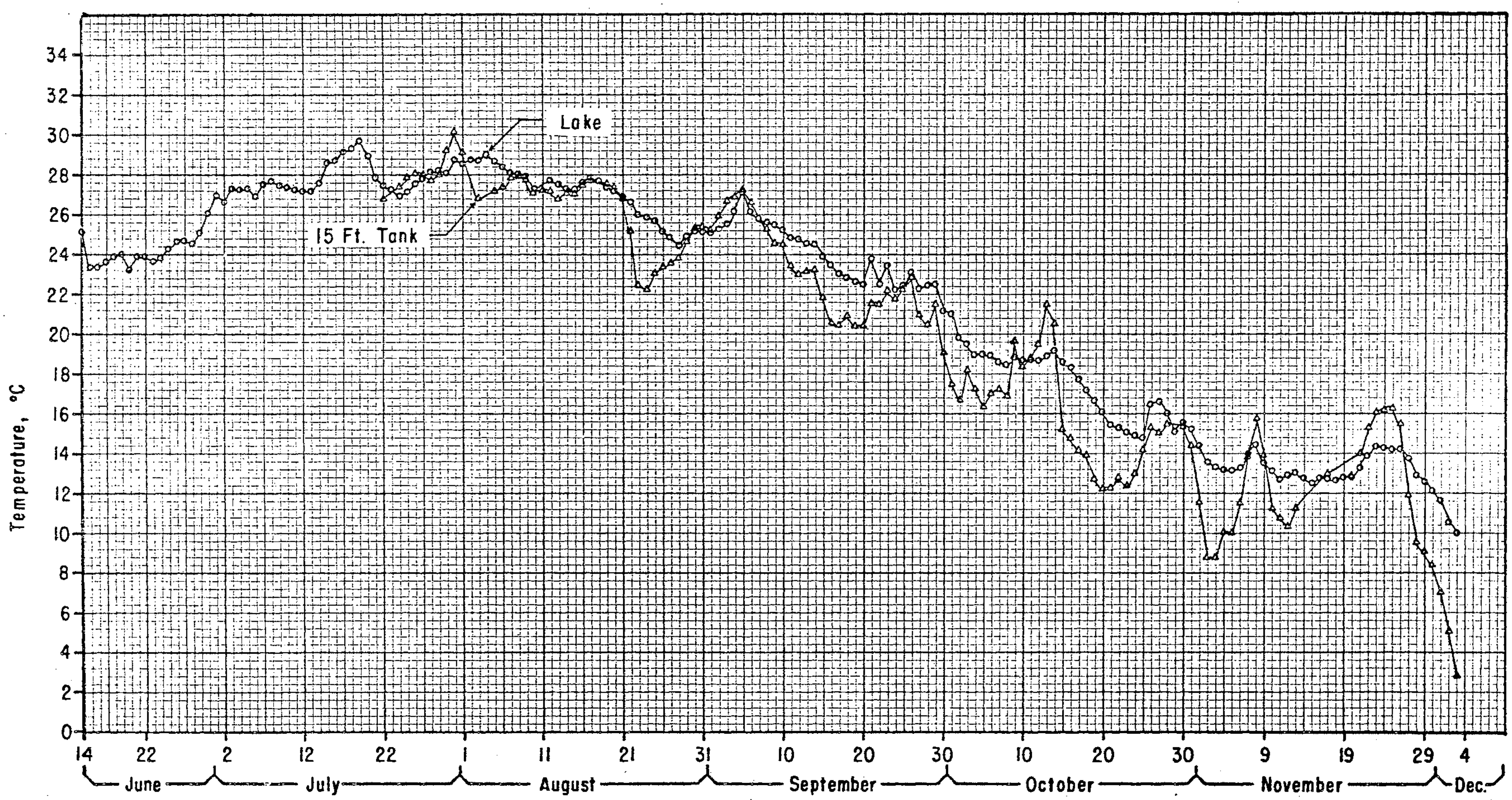


Figure 51. Water Surface Temperatures of Lake Hefner and the 15-Foot Tank During 1966.

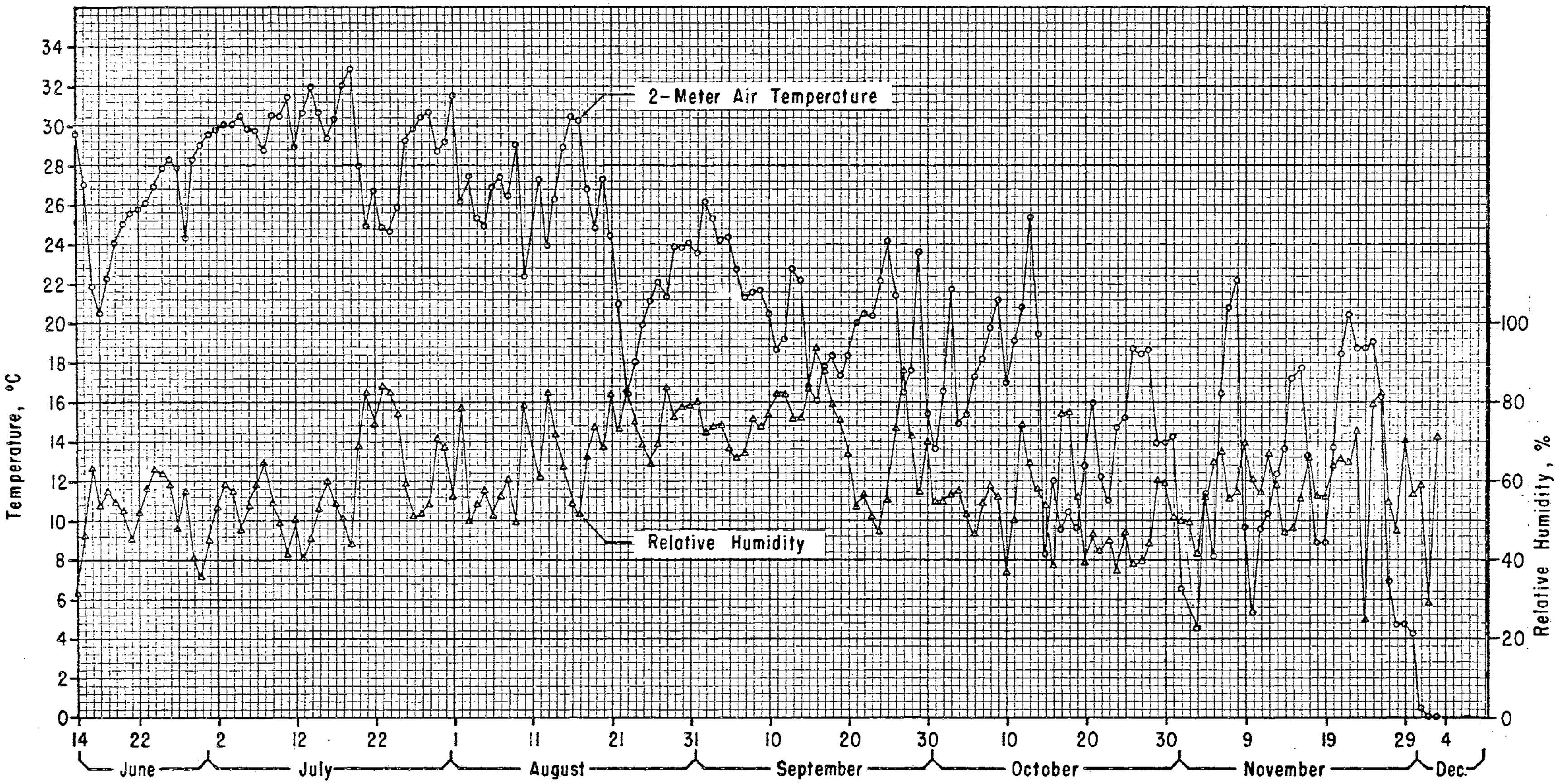


Figure 52. Record of 2-Meter Air Temperature and Relative Humidity at the South Instrument Station During 1966.

TABLE XIV

SUMMARY OF TEMPERATURE, PSYCHROMETRIC, AND EVAPORATION DATA FOR LAKE HEFNER AND THE SUNKEN TANKS

	Lake Hefner							15-Foot Tank						9-Foot Tank					
TSP	T_o	T_a	e_o	e_a	$(e_o-e_a)_L$	Rel Humidity	Water Budget Evap E_{wb}	T_o	e'_o	$(e'_o-e_a)_{15}$	Evap. E_{15}	$\frac{(e_o-e_a)_L}{(e'_o-e_a)_{15}}$	$\frac{E_{wb}}{E_{15}}$	T_o	e'_o	$(e'_o-e_a)_9$	Evap. E_9	$\frac{(e_o-e_a)_L}{(e'_o-e_a)_9}$	$\frac{E_{wb}}{E_9}$
	°C	°C	mb	mb	mb	%	in	°C	mb	mb	in			°C	mb	mb	in		
6	28.13	29.60	38.09	25.00	13.10	60.64	1.81	28.57	39.11	14.11	2.29	0.93	0.79	28.56	39.09	14.09	2.52	0.93	0.72
7	28.29	26.46	38.46	19.35	19.11	56.34	1.87	27.42	36.56	17.21	2.12	1.11	0.88	27.36	36.44	17.09	2.01	1.12	0.93
8	27.52	27.35	36.75	23.73	13.03	66.05	1.27	27.31	36.31	12.58	1.86	1.04	0.68	27.18	36.05	12.32	2.06	1.06	0.62
9	26.02	21.50	33.68	19.07	14.61	73.60	1.98	24.48	30.89	11.82	1.71	1.24	1.16	24.39	30.91	11.84	1.69	1.23	1.17
10	25.15	24.50	31.96	23.47	8.48	76.41	0.84	25.23	32.12	8.65	0.94	0.98	0.89	25.55	32.72	9.25	1.08	0.92	0.78
11	25.66	21.45	32.97	18.79	14.18	73.64	1.23	25.40	32.55	13.76	1.42	1.03	0.87	24.28	30.88	12.09	1.72	1.17	0.72
12	23.46	18.70	28.91	17.01	11.90	78.69	1.44	21.51	25.72	8.71	1.04	1.37	1.38	20.61	24.45	7.44	0.93	1.60	1.55
13	22.69	20.46	27.58	14.84	12.74	62.35	1.40	21.71	25.99	11.15	1.33	1.14	1.05	21.83	26.22	11.38	1.42	1.12	0.99
14	19.97	16.66	23.38	10.92	12.45	56.64	2.07	17.63	20.21	9.29	1.39	1.34	1.49	17.18	19.67	8.75	1.35	1.42	1.53
15	18.77	19.43	21.65	13.15	8.50	56.43	1.67	18.73	21.70	8.55	1.90	0.99	0.88	18.59	21.63	8.48	2.00	1.00	0.84
16	16.96	11.39	19.37	7.13	12.24	53.41	1.91	13.44	15.44	8.31	1.16	1.47	1.65	12.28	14.29	7.16	1.11	1.71	1.72
17	15.51	15.25	17.62	7.89	9.74	45.30	0.84	14.25	16.28	8.39	0.85	1.16	0.99	14.24	16.29	8.40	0.93	1.16	0.90
18	14.21	9.10	16.23	6.60	9.63	53.54	1.29	11.53	13.77	7.17	1.01	1.34	1.28	10.12	12.66	6.06	0.97	1.59	1.33
19	13.30	12.36	15.27	9.38	5.89	61.57	0.75	12.48	14.56	5.18	0.94	1.14	0.80	11.89	14.15	4.77	0.98	1.23	0.77
20	12.75	12.53	14.73	8.41	6.31	57.39	0.69	12.68	14.69	6.28	0.87	1.01	0.79	12.64	14.66	6.25	0.94	1.01	0.73
21	13.72	15.73	15.69	11.70	3.99	62.61	1.07	14.89	16.98	5.28	0.79	0.76	1.35	15.03	17.19	5.49	0.93	0.73	1.15
22	11.56	2.98	13.66	4.77	8.89	60.86	1.40	6.95	10.13	5.36	0.76	1.66	1.84	4.88	8.83	4.06	0.57	2.19	2.46

Development of a Lake Evaporation Prediction Equation

In Chapter IV a proposed equation for predicting lake evaporation was given:

$$E_{wb} = \frac{C_2(e_o - e_a)_L E_t}{(e_o' - e_a)_t} \tag{35}$$

The opportunity to test this equation was presented during the untreated TSP's in 1966. The Lake Hefner water budget evaporation data for untreated TSP's 9 and 12 to 18 were plotted against the product of vapor pressure deficit ratio and 15-foot tank evaporation. As shown in Figure 53, the equation for the least squares line passing through the origin is:

$$E_{wb} = 0.997 \frac{(e_o - e_a)_L E_{15}}{(e_o' - e_a)_{15}} \tag{60}$$

$R = 0.93^{**}$ Std. Dev. = 0.022

When Equation 60 is compared to Equation 59, which expressed lake evaporation as a function of 15-foot tank evaporation, it is apparent that the inclusion of the vapor pressure deficit ratio made a considerable improvement in the correlation coefficient and standard deviation. The 0.95 confidence interval for the regression line shown in Figure 53 indicates the extreme limits within which a regression line through the origin would be confined 95 percent of the time.

The corresponding linear regression equation for the line not passing through the origin is:

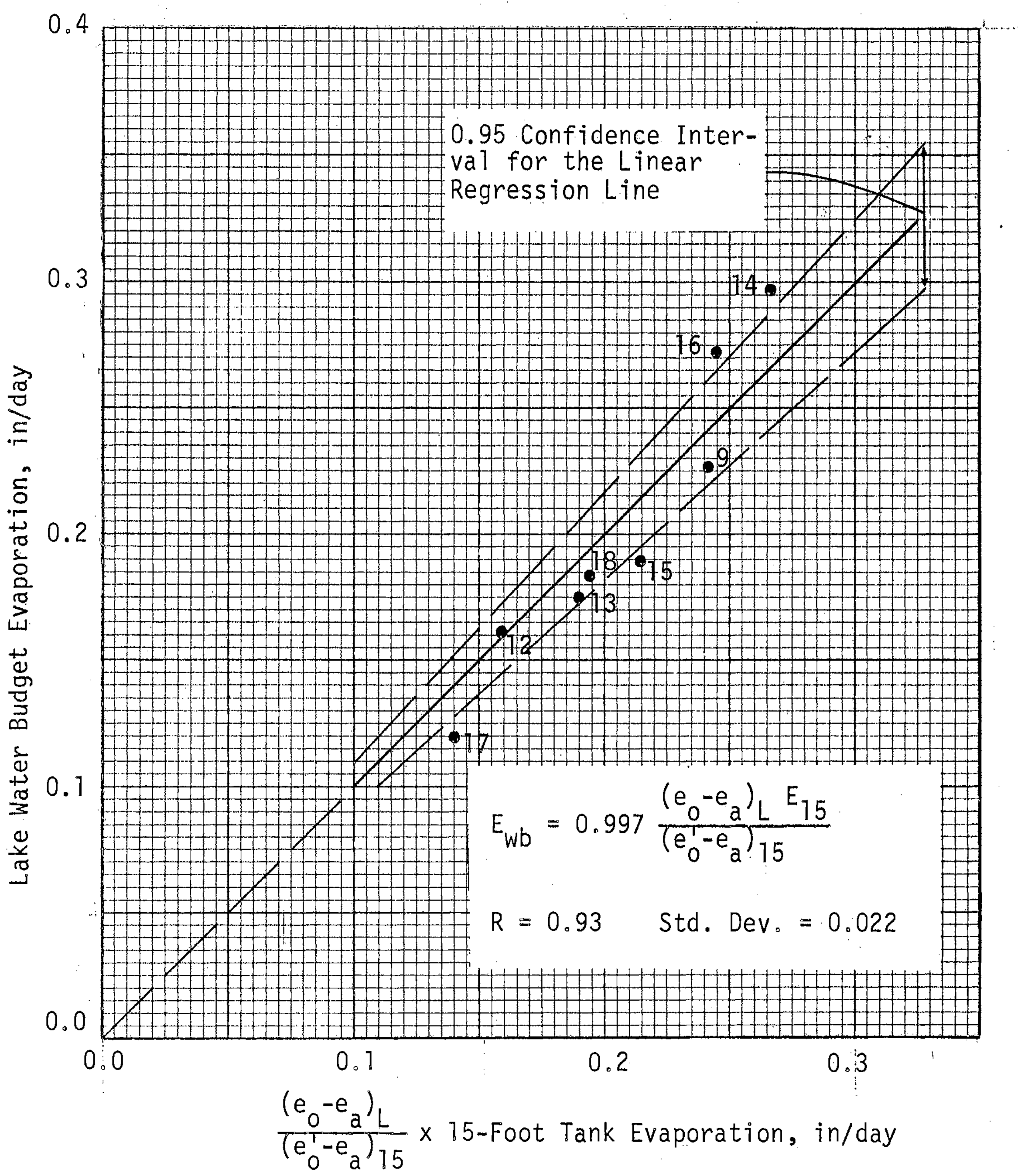


Figure 53. Lake Water Budget Evaporation as a Function of 15-Foot Tank Evaporation and the Vapor Pressure Deficit Ratio.

$$E_{wb} = -0.061 + \frac{1.28\ (e_o - e_a)_L\ E_{15}}{(e_o' - e_a)_{15}} \tag{61}$$

$R = 0.96^{**}$ Std. Dev. = 0.019

An analysis of variance test indicated that the difference between Equations 60 and 61 was not statistically significant at the 0.01 level. Since Equation 60 fits the theoretical model, it is considered the better equation.

The results of plotting the data from the Lake Hefner water budget and the 9-foot tank for TSP's 9 and 12 to 18 (Figure 54) are similar to those for the 15-foot tank. The linear regression equation of the line through the origin is:

$$E_{wb} = 0.939\ \frac{(e_o - e_a)_L\ E_9}{(e_o' - e_a)_{15}} \tag{62}$$

$R = 0.92^{**}$ Std. Dev. = 0.023

The least squares line not passing through the origin is:

$$E_{wb} = -0.74 + 1.263\ \frac{(e_o - e_a)_L\ E_9}{(e_o' - e_a)_9} \tag{63}$$

$R = 0.95^{**}$ Std. Dev. = 0.019

Equation 63 was not statistically better than Equation 62 at the 0.01 confidence level, and thus Equation 62 is considered the better equation because it fits the theoretical model.

Use of the Lake Evaporation Prediction Equation During Treated Periods

As a test to determine whether Equation 60 was adequate for detecting lake evaporation reduction during treated TSP's, the 0.95

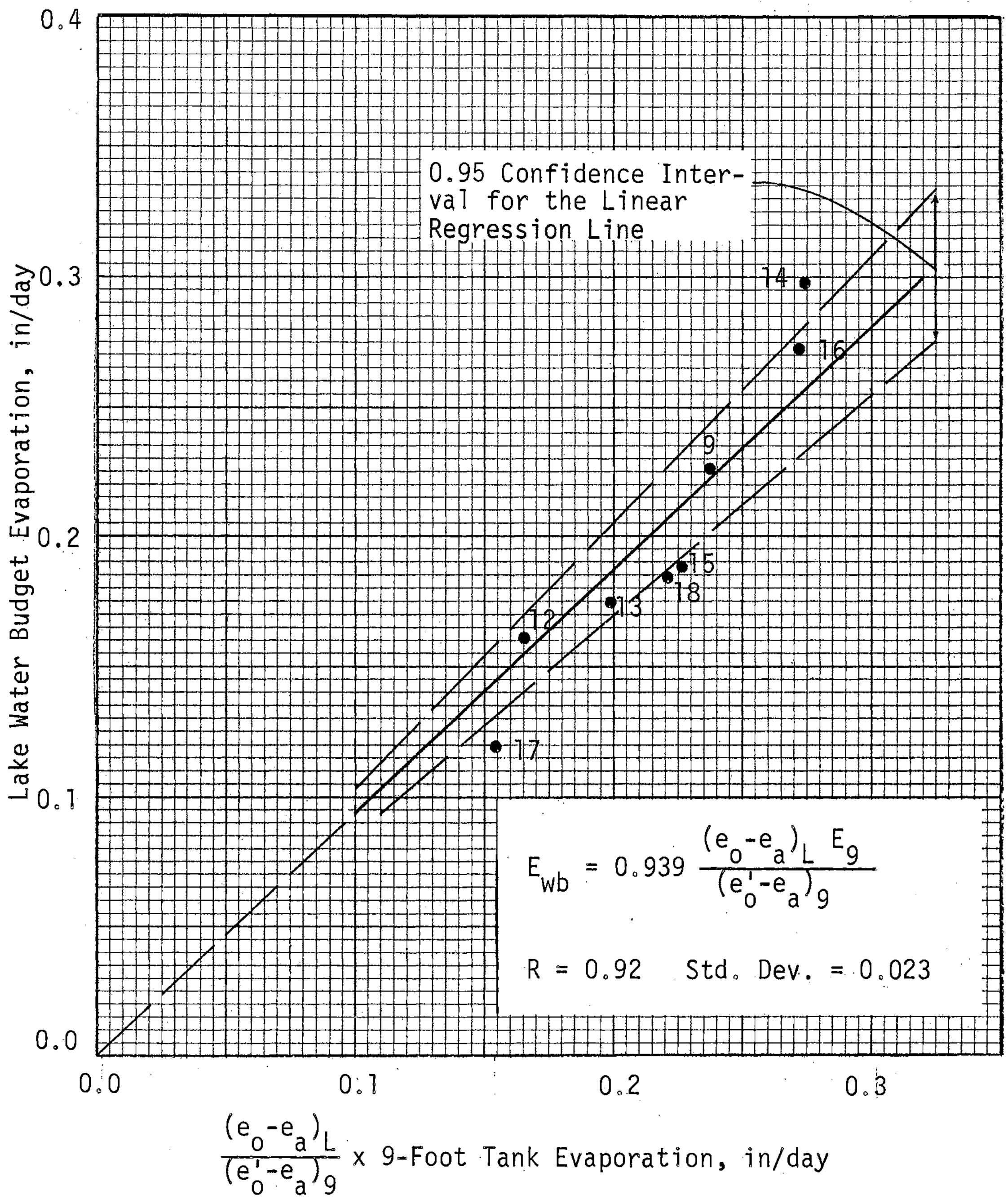


Figure 54. Lake Water Budget Evaporation as a Function of 9-Foot Tank Evaporation and the Vapor Pressure Deficit Ratio.

confidence interval for a single future value of Y corresponding to a given X for Equation 60 was plotted in Figure 55 along with the data from the five treated TSP's. TSP's 7 and 8 fall outside the 0.95 confidence interval estimates, indicating a possible treatment effect during these periods. Furthermore, all the treated TSP's fall in a consistent pattern to the right of the regression line. No attempt was made to estimate the magnitude of the evaporation reductions suggested by Figure 55. For reference in interpreting this data, a portion of the results of the Lake Hefner evaporation suppression study is summarized in Table XV (8).

TABLE XV

EVAPORATION SUPPRESSION COMPUTED BY SIMPLIFIED METHOD, LAKE HEFNER 1966

TSP	Average Portion of Lake Covered With Film %	Estimated Evaporation Reduction Computed By Simplified Method %
6	24	9.7
7	24	11.5
8	27	13.5
10	22	12.3
11	39	20.0

The 0.95 confidence interval estimate for a single future value of Y corresponding to a given X for Equation 62 for the 9-foot tank was plotted in Figure 56, along with the data from the treated TSP's. The data indicate a treatment effect for TSP's 8 and 11. Although there is not exact agreement between the equations for the 15-foot and the 9-foot tank, the general agreement is fairly good, because TSP's 7, 8, and 11 were periods of high film cover on the lake.

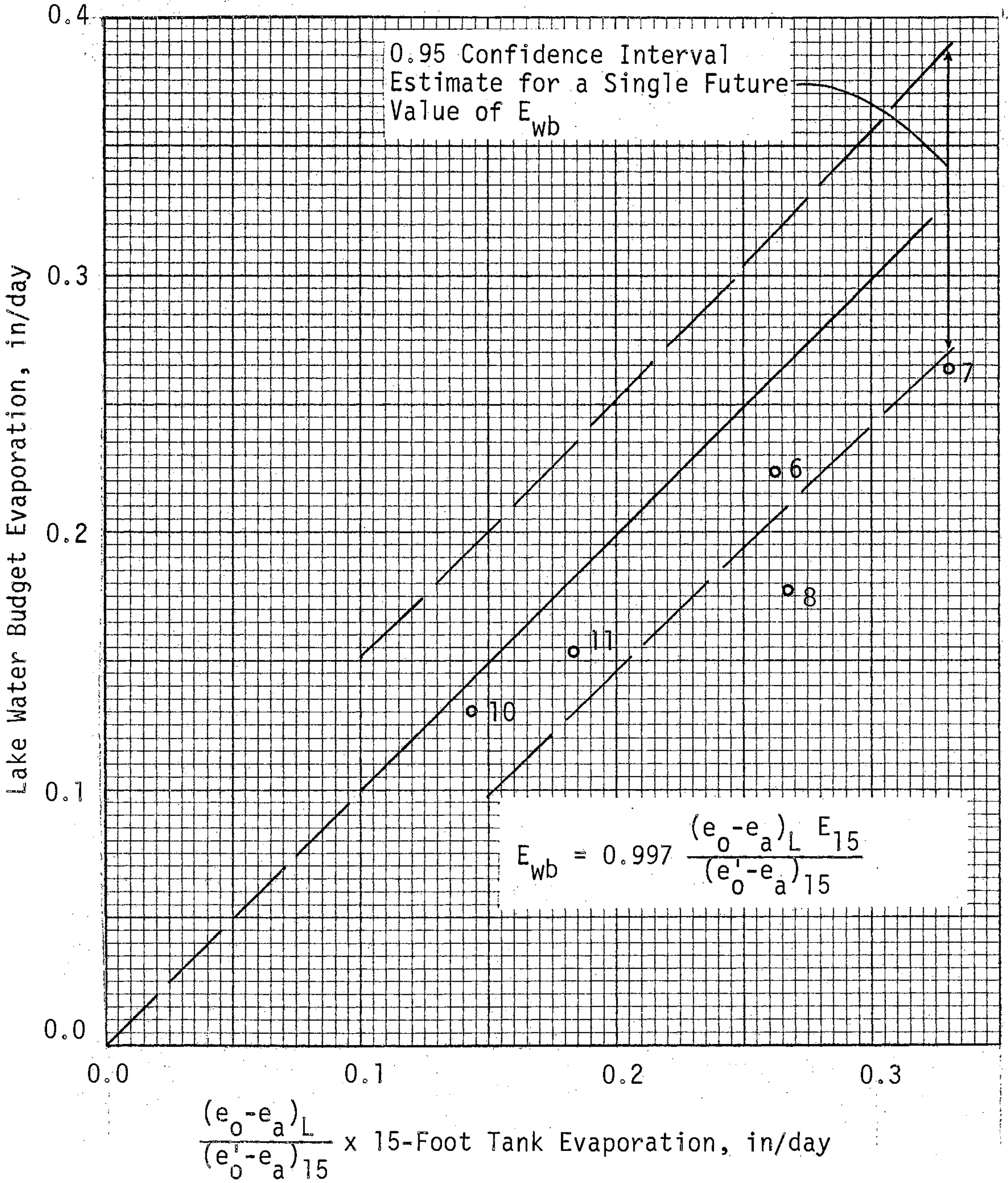


Figure 55. Comparison of Lake Evaporation During Treated TSP's with the Lake Evaporation Predicted from 15-Foot Tank Evaporation.

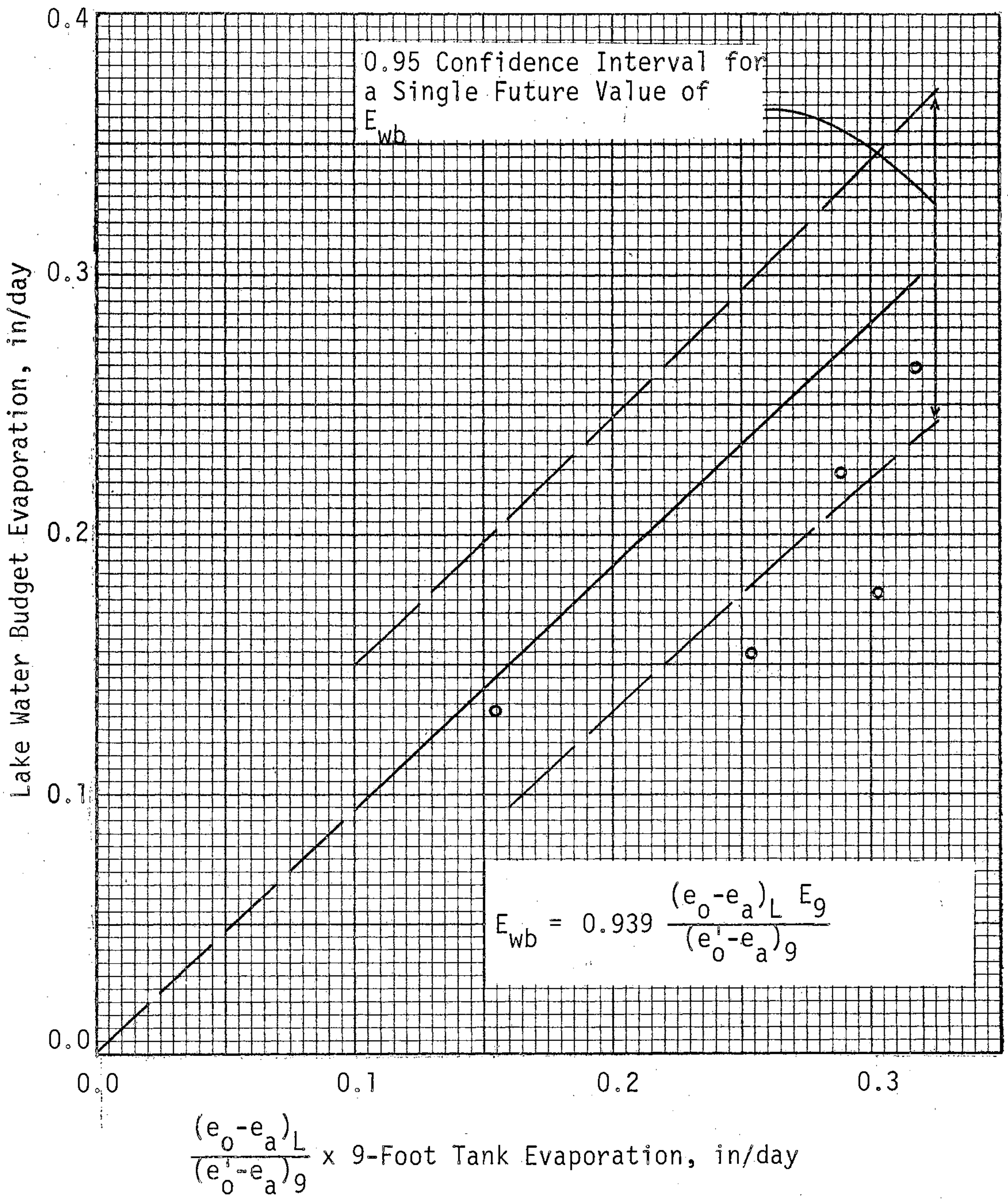


Figure 56. Comparison of Lake Evaporation During Treated TSP's with the Lake Evaporation Predicted from 9-Foot Tank Evaporation.

Discussion of Heat Losses from the Sunken Tanks

The heat flux through the bottom and sides of the sunken tanks was not measured. However, the temperature profiles of the 9-foot and 15-foot tanks (previously discussed on Page 106) provided some indication of the magnitude of heat losses to the soil. The temperatures near the bottom of the tanks were almost isothermal, indicating that heat transfer through the bottom and lower sides of the tanks was small compared with the heat transfer at the water surface.

In a similar evaporation study, Nordenson and Baker (33) found that an uninsulated sunken pan 6 feet in diameter and 2 feet in depth experienced lower evaporation rates and thus higher heat losses to the soil than an insulated pan during a 902-day period at Silver Hill, Maryland. The heat losses varied seasonally, being largest in the summer. The sunken tanks at Lake Hefner may have experienced similar heat losses and reduced evaporation rates. This may not have affected the accuracy of the lake evaporation prediction equation, because the evaporation from the sunken tanks was proportional to the vapor pressure deficit ($e_o' - e_a$), and a loss of heat through the bottom and sides of the tank should have been reflected in this term.

Effect of Tank Size on the Prediction Equation

Figure 57 shows the regression lines for Equations 60, 62, and 37 for the 15-foot and 9-foot tanks and Class A pan, respectively. Equation 37 was derived from data published by Kohler (49) in the 1950-51 Lake Hefner report. It is apparent that the coefficient C_2 approaches unity for the larger tanks. A slope of unity in Figure 57 would seem to represent the optimum size of tank for predicting lake evaporation

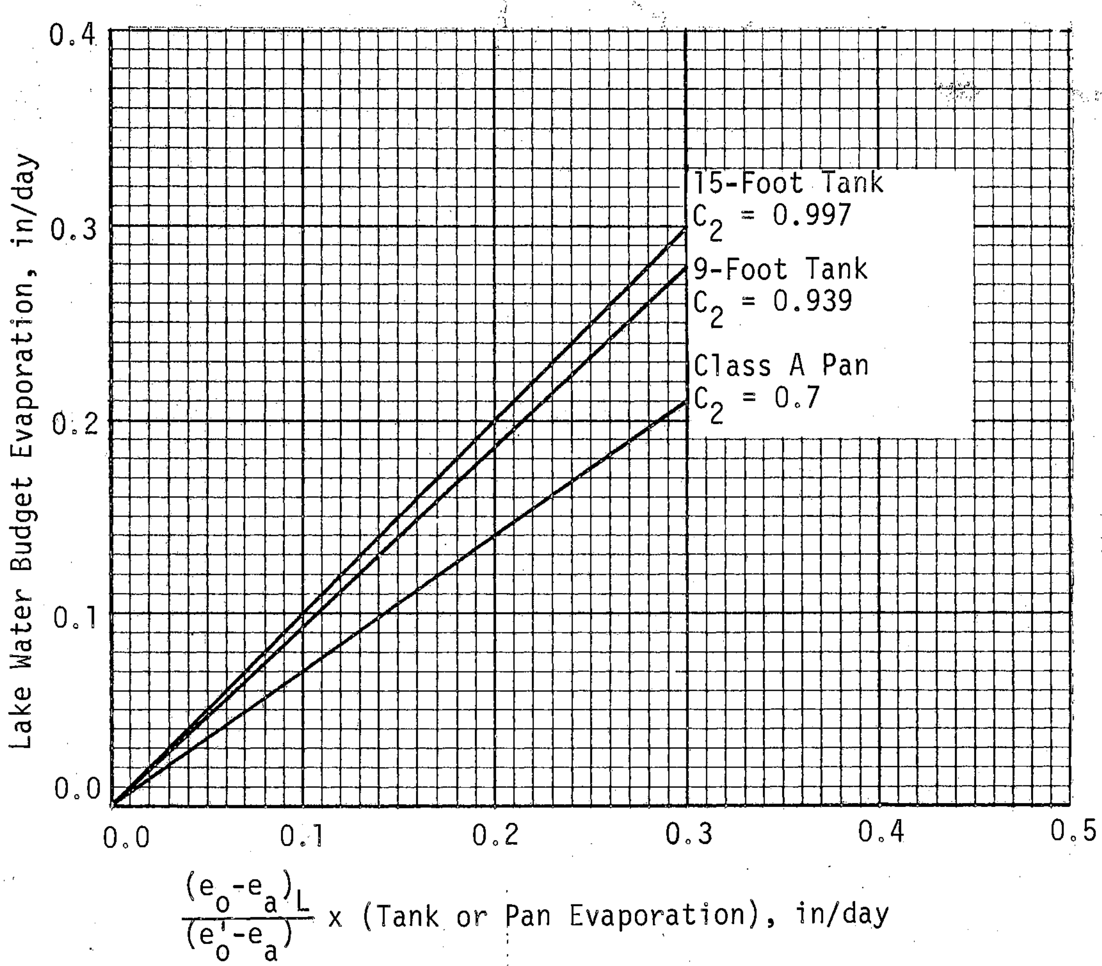


Figure 57. The Effect of Tank Size on the Coefficient C_2 in the Lake Evaporation Prediction Equations.

from the product of tank evaporation and the vapor pressure deficit ratio. Presumably, a slope of unity would occur if one were comparing adjacent lakes instead of a lake and a tank. Although the water surface temperature and lake/tank ratio varied more for the 9-foot tank than the 15-foot tank, the fit of the data to the theoretical model was equally good for the two sizes of tanks.

The 15-foot tank possessed two distinct advantages over the Class A pan during this study. No problem was experienced with overflow from the 15-foot tank during heavy rains, because the average distance from the rim to the water surface of the tank was 5 inches. Furthermore, the greater diameter of the 15-foot tank minimized any splash out that might have occurred. On the other hand, when rains of 2 inches or more occurred, discarding of evaporation data from the Class A pans was usually necessary because of overflow and splash out.

Effect of Tank Size on the Mass Transfer Coefficient N

Appendix F lists the values of the mass transfer coefficient N, as defined by Equation 5, for Lake Hefner, the 15-foot tank, and the 9-foot tank, respectively. The values of N are inversely proportional to the size of the body of water. This inverse relationship is in agreement with an observation of Harbeck (17), who noted that the values of N for several lakes ranging in size from 1 to 30,000 acres were smaller for the larger lakes.

Comparison of the Prediction Equation with the Energy Budget Method

The lake evaporation prediction equation (Equation 60) had a higher correlation coefficient and a lower standard deviation than the linear regression equation of E_{eb} versus E_{wb} (Equation 43). The correlation coefficients of the two equations were not significantly different at the 0.01 confidence level. However, some question arises about whether or not the relationship of Equation 43 could be used with confidence on a future occasion, because of suspected errors in the energy budget.

Also, the energy budget evaporation was derived from a much more complicated set of input data, and its computation required considerably more effort than did the prediction equation or the water budget.

The most serious shortcoming of the evaporation prediction equation is that it was derived from less than one year of observations. Obviously, before the prediction equation can be widely used, it should be verified or modified by a series of full year studies at other locations.

Comparison of the Prediction Equation with the Weather Bureau Method

Figure 58 is a plot of lake water budget evaporation versus evaporation predicted by the Weather Bureau method. The predicted evaporation was lower than the lake evaporation for 17 of 19 untreated TSP's in 1965 and 1966. The correlation coefficient of the linear regression equation shown in Figure 58 was considerably lower than that of the lake evaporation prediction equation (Equation 60).

Figure 59 is a similar plot of 15-foot tank evaporation versus the evaporation predicted by the Weather Bureau method. The scatter of the data is much less than in Figure 58. The good fit of the predicted

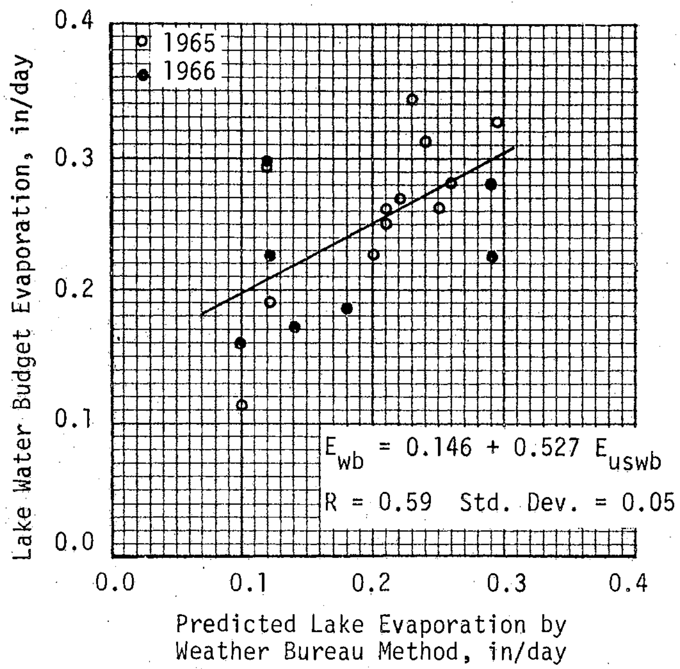


Figure 58. Comparison of Lake Evaporation with that Predicted by the Weather Bureau Method.

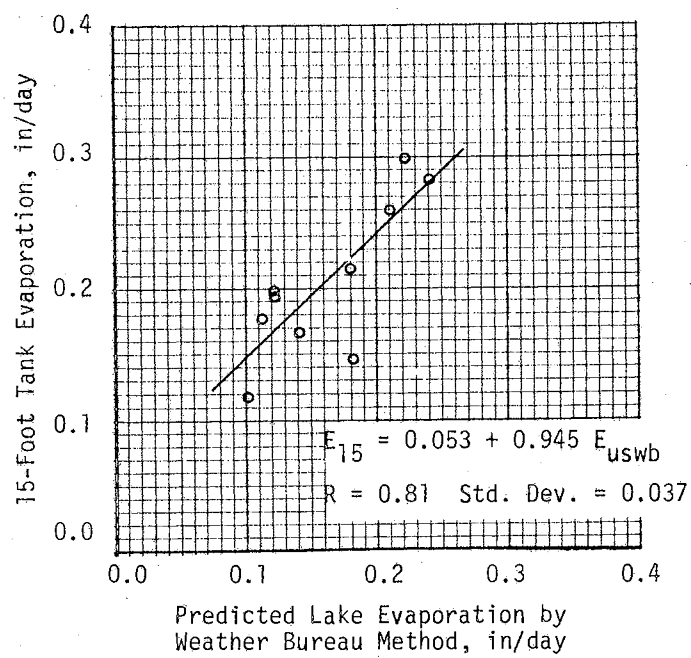


Figure 59. Comparison of 15-Foot Tank Evaporation with that Predicted by the Weather Bureau Method.

evaporation to the 15-foot tank evaporation is in general agreement with the results of a somewhat similar study by Nordenson and Baker (33).

CHAPTER XI

SUMMARY AND CONCLUSIONS

Summary

The objectives of this study were to: 1. Evaluate the accuracy of the energy budget method of estimating evaporation from Lake Hefner. 2. Investigate the effect of temperature, wind, and surface area of a body of water upon the evaporation reduction achieved by means of a monomolecular film. 3. Investigate the relationship between lake evaporation and evaporation from large sunken tanks and a pond.

Energy Budget Studies

A large scale investigation of evaporation was carried out at Lake Hefner, Oklahoma, during the spring, summer, and fall of 1965 and 1966. The lake evaporation was measured using (1) a water budget method of proven accuracy, and (2) an energy budget method. The water budget method was a simple summing up of all water entering and leaving the lake, while the energy budget evaporation was computed from the net flux of thermal energy entering and leaving the lake.

The energy budget evaporation exceeded the water budget evaporation by about 20 percent during both 1965 and 1966. Each of the terms in the energy budget was examined as a possible source of error and it was concluded that the probable source of error was in the measurement of the atmospheric radiation, Q_a, by the flat plate radiometer.

Pan and Tank Evaporation Reduction Studies

During the 1966 season, evaporation records were maintained for four pairs of evaporation vessels. One of each pair was continuously treated with a monolayer forming mixture of hexadecanol and octadecanol. The evaporation vessels consisted of standard Class A pans, sunken Class A pans, and sunken 4-foot and 9-foot diameter stock tanks. The evaporation reductions during the period August 16 to December 4, 1966, were: Class A pan, 63.3 percent; sunken 4-foot tank, 62 percent; sunken Class A pan, 58.6 percent; and, sunken 9-foot tank, 44.5 percent.

The sunken 9-foot tank had the lowest evaporation reduction, apparently because the wind blew the monomolecular film to one side. The treated vessels experienced an average temperature rise ranging from 2.14°C for the sunken Class A pan to 3.14°C for the Class A pan. The evaporation reduction was inversely related to water surface temperature for all evaporation vessels. A graph of data from this and six other recent studies in the western United States indicated that evaporation reductions from bodies of water ranging up to 3000 acres could be expressed by:

$$ER = 62.5\ A^{-0.092}$$

where

ER = evaporation reduction, percent

A = area of body of water, ft^2

Lake/Tank Evaporation Studies

The most important objective of this study was to investigate the relationship between lake evaporation and evaporation from large sunken tanks and a pond. During 1965 and 1966 evaporation records were obtained for a 0.28-acre pond at Stillwater, 60 miles northeast of Lake Hefner, and during 1966, daily records of evaporation were maintained for sunken 9-foot and 15-foot tanks located adjacent to Lake Hefner. The average lake/tank evaporation ratio for both the 15-foot and 9-foot tanks was 1.01. The average lake/pond evaporation ratio was 1.03 in 1965 and 1.17 in 1966. The lake/tank and lake/pond evaporation ratios increased during the fall of the year because the pond and tanks cooled more rapidly than the lake.

The 15-foot tank and the 0.28-acre pond had similar evaporation rates despite the 60-mile distance between their locations. The 15-foot tank provided as good an estimate of lake evaporation as did the 0.28-acre pond.

Evaporation Prediction Equation

A prediction equation was developed using evaporation rates and water surface temperatures of the lake and 15-foot tank, plus the 2-meter air temperature and relative humidity:

$$E_{wb} = 0.997 \frac{(e_o - e_a)_L \, E_{15}}{(e_o' - e_a)_{15}} \tag{62}$$

$R = 0.93$ Std. Dev. $= 0.022$

This prediction equation and a similar equation for the 9-foot tank were simpler and gave more accurate results than the energy budget method. They also provided a better estimate of evaporation at Lake Hefner than an evaporation prediction method in use by the U.S. Weather Bureau.

Conclusions

The following conclusions are based on the interpretation of the experimental results:

1. The evaporation estimated by the energy budget method exceeded the lake water budget evaporation by about 20 percent, probably because of errors in the measurement of the atmospheric radiation, Q_a, by the flat plate radiometer.
2. Evaporation reductions caused by treatment with monomolecular films are inversely related to water surface temperature for standard Class A pans and for sunken pans and tanks ranging up to 9 feet in diameter. The evaporation reduction was inversely related to the diameter of the sunken 4-foot and 9-foot tanks, apparently because the wind blew the film to one side of the larger tank.
3. Under the climatic conditions that prevailed during this study, the total evaporation amounts for the 9-foot and 15-foot tanks and 0.28-acre pond were approximately equal to lake evaporation, but there was a large seasonal variation in the lake/tank and lake/pond evaporation ratios.
4. The evaporation from Lake Hefner can be satisfactorily estimated by an equation which expresses lake evaporation as a linear function of the product of 15-foot tank evaporation and the ratio of the vapor pressure deficits over the lake and the tank, respectively.

Recommendations for Further Research

In order to realize full benefit from the concepts developed in this study, the following additional work is needed:

1. Evaporation studies should be initiated at Lake Hefner and at least two other lakes to test the validity of the evaporation prediction equation developed at Lake Hefner. Ideally, each study would consist of at least two full years of water budget evaporation records from a lake, an insulated 15-foot sunken tank, and a pond. The only other data required would be the 2-meter wind speed, the wet-bulb and dry-bulb temperatures, and surface water temperatures of the lake, pond, and tank. The experience gained in the current study has shown that weekly measurements of evaporation would be adequate for purposes of comparison. Such a study would require only one service trip to the lake area each week. The computer programs and data handling techniques for processing the data have already been organized.
2. To enhance the value of the evaporation data, the stored energy in the lake, tank, and pond should be monitored by means of thermocouples placed at various depths.

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APPENDIX A

DAILY WATER BUDGET, 1965

DAILY WATER BUDGET, 1966

TABLE XVI

DAILY WATER BUDGET, 1965

TS PERIOD 01   12.50 06/03/65 TO 08.00 06/10/65

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
6 3	1230	2236.76	1192.445									
6 3	2400	2236.28	1192.439	-0.0060	0.0061	0.0003	0.0003	0.0055	0.0000	0.0006	0.0648	0.1646
6 4	2400	2235.33	1192.422	-0.0170	0.0103	0.0005	0.0006	0.0106	0.0017	0.0006	0.2208	0.5608
6 5	2400	2234.37	1192.402	-0.0200	0.0156	0.0006	0.0007	0.0098	0.0098	0.0006	0.2796	0.7102
6 6	2400	2233.89	1192.386	-0.0160	0.0197	0.0006	0.0006	0.0087	0.0000	0.0006	0.0528	0.1341
6 7	2400	2231.50	1192.340	-0.0460	0.0322	0.0006	0.0004	0.0081	0.0000	0.0006	0.2580	0.6553
6 8	2400	2232.93	1192.370	0.0300	0.0378	0.0006	0.0003	0.0606	0.0000	0.0007	-0.0888	-0.2255
6 9	2400	2237.24	1192.462	0.0920	0.0358	0.0006	0.0003	0.1345	0.0000	0.0007	0.0780	0.1981
6 10	800	2237.72	1192.468	0.0060	0.0103	0.0002	0.0001	0.0203	0.0000	0.0006	0.0516	0.1311
TOTALS				0.0230	0.1678	0.0041	0.0033	0.2581	0.0115	0.0050	0.9168	2.3286

TS PERIOD 02   08.00 06/10/65 TO 08.00 06/17/65

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
6 10	800	2237.72	1192.468									
6 10	2400	2238.68	1192.494	0.0260	0.0207	0.0004	0.0002	0.0421	0.0000	0.0007	-0.0540	-0.1372
6 11	2400	2242.51	1192.567	0.0730	0.0254	0.0005	0.0003	0.0990	0.0000	0.0007	0.0048	0.0122
6 12	2400	2249.21	1192.714	0.1470	0.0096	0.0006	0.0007	0.1049	0.0479	0.0006	-0.0540	-0.1372
6 13	2400	2263.56	1193.009	0.2950	0.0097	0.0006	0.0009	0.1847	0.0938	0.0006	-0.3252	-0.8260
6 14	2400	2291.80	1193.597	0.5880	0.0140	0.0005	0.0007	0.5812	0.0000	0.0006	-0.2580	-0.6553
6 15	2400	2316.69	1194.115	0.5180	0.0114	0.0006	0.0006	0.5417	0.0000	0.0006	0.1404	0.3566
6 16	2400	2328.65	1194.374	0.2590	0.0136	0.0006	0.0006	0.2894	0.0000	0.0006	0.1944	0.4938
6 17	800	2331.52	1194.430	0.0560	0.0049	0.0002	0.0002	0.0750	0.0000	0.0006	0.1716	0.4358
TOTALS				1.9620	0.1093	0.0042	0.0042	1.9180	0.1417	0.0050	-0.1800	-0.4572

TS PERIOD 03   08.00 06/17/65 TO 08.00 06/24/65

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
6 17	800	2331.52	1194.430									
6 17	2400	2337.75	1194.558	0.1280	0.0099	0.0004	0.0004	0.1374	0.0000	0.0006	-0.0084	-0.0213
6 18	2400	3454.02	1194.902	0.3440	0.0149	0.0006	0.0004	0.3726	0.0000	0.0005	0.1584	0.4023
6 19	2400	2371.62	1195.270	0.3680	0.0169	0.0006	0.0003	0.4124	0.0000	0.0005	0.3252	0.8260
6 20	2400	2388.70	1195.628	0.3580	0.0176	0.0006	0.0004	0.4094	0.0000	0.0006	0.4008	1.0180
6 21	2400	2413.54	1196.093	0.4650	0.0203	0.0006	0.0003	0.4115	0.1138	0.0006	0.4764	1.2100
6 22	2400	2443.28	1196.782	0.6890	0.0153	0.0006	0.0007	0.7465	0.0000	0.0005	0.4968	1.2618
6 23	2400	2480.30	1197.557	0.7750	0.0160	0.0005	0.0006	0.9188	0.0000	0.0005	1.5252	3.8739
6 24	800	2490.27	1197.767	0.2100	0.0055	0.0002	0.0002	0.1842	0.0000	0.0006	-0.3732	-0.9479
TOTALS				3.3370	0.1164	0.0042	0.0033	3.5928	0.1138	0.0044	3.0012	7.6227

TS PERIOD 04   08.00 06/24/65 TO 08.30 07/01/65

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
6 24	800	2490.27	1197.767									
6 24	2400	2508.78	1198.160	0.3930	0.0111	0.0004	0.0004	0.3683	0.0350	0.0009	-0.0084	-0.0213
6 25	2433	2535.36	1198.718	0.5580	0.0158	0.0005	0.0007	0.5987	0.0504	0.0009	0.8988	2.2829
6 26	2400	2563.36	1199.312	0.5940	0.0141	0.0005	0.0006	0.6175	0.0000	0.0009	0.1092	0.2774
6 27	2400	2570.00	1199.446	0.1340	0.0103	0.0006	0.0006	0.1992	0.0000	0.0009	0.6552	1.6641
6 28	2400	2570.95	1199.473	0.0270	0.0194	0.0006	0.0006	0.0644	0.0000	0.0009	0.2124	0.5395
6 29	2400	2569.05	1199.433	-0.0400	0.0169	0.0006	0.0006	0.0011	0.0000	0.0009	0.2868	0.7284
6 30	2400	2567.15	1199.394	-0.0390	0.0276	0.0006	0.0005	0.0005	0.0000	0.0009	0.1404	0.3566
7 1	830	2566.21	1199.374	-0.0200	0.0100	0.0002	0.0001	0.0002	0.0000	0.0008	0.1284	0.3261
TOTALS				1.6070	0.1252	0.0042	0.0041	1.8499	0.0854	0.0071	2.4228	6.1537

TS PERIOD 05   08.30 07/01/65 TO 08.30 07/08/65

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
7 1	830	2566.21	1199.374									
7 1	2400	2564.78	1199.335	-0.0390	0.0183	0.0004	0.0003	0.0003	0.0000	0.0006	0.2508	0.6370
7 2	2400	2561.93	1199.276	-0.0590	0.0298	0.0006	0.0004	0.0061	0.0000	0.0006	0.4188	1.0637
7 3	2400	2560.51	1199.250	-0.0260	0.0270	0.0006	0.0004	0.0170	0.0000	0.0007	0.1884	0.4785
7 4	2400	2559.09	1199.217	-0.0330	0.0202	0.0006	0.0004	0.0066	0.0000	0.0007	0.2292	0.5821
7 5	2400	2556.71	1199.174	-0.0430	0.0285	0.0006	0.0004	0.0051	0.0000	0.0006	0.2304	0.5852
7 6	2400	2557.19	1199.166	-0.0080	0.0174	0.0006	0.0006	0.0058	0.0239	0.0006	0.2364	0.6004
7 7	2400	2556.24	1199.158	-0.0080	0.0185	0.0006	0.0006	0.0045	0.0240	0.0006	0.2088	0.5303
7 8	830	2555.76	1199.145	-0.0130	0.0072	0.0002	0.0002	0.0015	0.0000	0.0006	0.0900	0.2286
TOTALS				-0.2290	0.1669	0.0042	0.0033	0.0469	0.0479	0.0050	1.8528	4.7059

TS PERIOD 06   08.30 07/08/65 TO 08.30 07/15/65

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
7 8	830	2555.76	1199.145									
7 8	2400	2554.81	1199.128	-0.0170	0.0131	0.0004	0.0004	0.0019	0.0000	0.0001	0.0612	0.1554
7 9	2400	2552.92	1199.086	-0.0420	0.0217	0.0006	0.0006	0.0003	0.0008	0.0000	0.2424	0.6157
7 10	2400	2550.54	1199.043	-0.0430	0.0255	0.0006	0.0006	0.0002	0.0000	0.0000	0.1980	0.5029
7 11	2400	2547.70	1198.981	-0.0620	0.0280	0.0006	0.0005	0.0001	0.0000	0.0000	0.3960	1.0058
7 12	2400	2544.85	1198.915	-0.0660	0.0303	0.0006	0.0004	0.0000	0.0000	0.0000	0.4164	1.0576
7 13	2400	2542.00	1198.862	-0.0530	0.0265	0.0006	0.0004	0.0002	0.0000	0.0000	0.3084	0.7833
7 14	2400	2539.63	1198.810	-0.0520	0.0260	0.0006	0.0004	0.0003	0.0000	0.0001	0.3048	0.7742
7 15	830	2539.15	1198.797	-0.0130	0.0088	0.0002	0.0001	0.0003	0.0000	0.0001	0.0516	0.1311
TOTALS				-0.3480	0.1799	0.0042	0.0034	0.0033	0.0008	0.0003	1.9788	5.0260

TABLE XVI (Continued)

TS PERIOD 07 08.30 07/15/65 TO 08.30 07/22/65

DATE TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	WITHDRAWALS SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
7 15 830	2539.15	1198.797									
7 15 2400	2537.73	1198.774	-0.0230	0.0160	0.0004	0.0003	0.0000	0.0000	-0.0001	0.0744	0.1890
7 16 2400	2535.83	1198.728	-0.0460	0.0239	0.0006	0.0004	0.0000	0.0000	0.0000	0.2532	0.6431
7 17 2400	2533.46	1198.679	-0.0490	0.0246	0.0006	0.0004	0.0002	0.0000	-0.0001	0.2820	0.7163
7 18 2400	2530.61	1198.616	-0.0630	0.0309	0.0006	0.0004	0.0002	0.0000	-0.0001	0.3744	0.9509
7 19 2400	2526.81	1198.541	-0.0750	0.0325	0.0006	0.0004	0.0002	0.0000	-0.0001	0.4992	1.2679
7 20 2400	2523.49	1198.469	-0.0720	0.0354	0.0006	0.0004	0.0001	0.0000	-0.0001	0.4272	1.0850
7 21 2400	2520.64	1198.406	-0.0630	0.0351	0.0005	0.0003	0.0000	0.0000	0.0000	0.3240	0.8229
7 22 830	2519.69	1198.387	-0.0190	0.0129	0.0002	0.0001	0.0001	0.0000	-0.0001	0.0696	0.1768
TOTALS			-0.4100	0.2113	0.0042	0.0027	0.0008	0.0000	-0.0006	2.3040	5.8519

TS PERIOD 08 08.30 07/22/65 TO 08.00 07/29/65

DATE TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	WITHDRAWALS SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
7 22 830	2519.69	1198.380									
7 22 2400	2517.32	1198.344	-0.0430	0.0235	0.0004	0.0003	0.0001	0.0000	0.0002	0.2292	0.5821
7 23 2400	2514.47	1198.275	-0.0690	0.0370	0.0006	0.0003	0.0002	0.0000	0.0002	0.3780	0.9601
7 24 2400	2512.10	1198.226	-0.0490	0.0294	0.0006	0.0003	0.0001	0.0031	0.0002	0.2652	0.6736
7 25 2400	2512.10	1198.233	0.0070	0.0169	0.0006	0.0004	0.0000	0.0442	0.0001	0.2328	0.5913
7 26 2400	2510.68	1198.200	-0.0330	0.0202	0.0006	0.0005	0.0000	0.0000	0.0002	0.1428	0.3627
7 27 2400	2512.10	1198.209	0.0090	0.0193	0.0006	0.0004	0.0002	0.0453	0.0002	0.1968	0.4999
7 28 2400	2511.63	1198.219	0.0100	0.0050	0.0006	0.0006	0.0003	0.0453	0.0002	0.3552	0.9022
7 29 800	2511.15	1198.210	-0.0090	0.0003	0.0002	0.0002	0.0001	0.0000	0.0002	0.1032	0.2621
TOTALS			-0.1770	0.1516	0.0042	0.0030	0.0010	0.1379	0.0015	1.9032	4.8339

TS PERIOD 09 08.00 07/29/65 TO 08.30 08/05/65

DATE TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	WITHDRAWALS SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
7 29 800	2511.15	1198.210									
7 29 2400	2510.20	1198.187	-0.0230	0.0007	0.0004	0.0004	0.0001	0.0000	-0.0007	0.2508	0.6370
7 30 2400	2509.25	1198.173	-0.0170	0.0054	0.0006	0.0006	0.0002	0.0000	-0.0008	0.1176	0.2987
7 31 2400	2507.35	1198.128	-0.0420	0.0089	0.0006	0.0006	0.0002	0.0000	-0.0008	0.3756	0.9540
8 1 2400	2505.93	1198.099	-0.0300	0.0088	0.0006	0.0006	0.0001	0.0000	-0.0007	0.2328	0.5913
8 2 2400	2504.51	1198.068	-0.0300	0.0087	0.0006	0.0005	0.0000	0.0000	-0.0007	0.2340	0.5943
8 3 2400	2502.61	1198.026	-0.0420	0.0093	0.0006	0.0004	0.0002	0.0000	-0.0008	0.3732	0.9479
8 4 2400	2500.24	1197.980	-0.0460	0.0088	0.0005	0.0003	0.0002	0.0000	-0.0008	0.4284	1.0881
8 5 830	2499.29	1197.960	-0.0200	0.0032	0.0002	0.0001	0.0000	0.0000	-0.0008	0.1884	0.4785
TOTALS			-0.2500	0.0538	0.0042	0.0035	0.0010	0.0000	-0.0061	2.2008	5.5898

TS PERIOD 10 10.30 08/09/65 TO 10.00 08/16/65

DATE TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	WITHDRAWALS SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
8 9 1030	2512.58	1198.236									
8 9 2400	2512.10	1198.229	-0.0070	0.0049	0.0003	0.0003	0.0002	0.0000	-0.0000	0.0204	0.0518
8 10 2400	2511.63	1198.219	-0.0100	0.0088	0.0006	0.0011	0.0012	0.0125	-0.0005	0.1524	0.3871
8 11 2400	2510.20	1198.187	-0.0320	0.0092	0.0006	0.0011	0.0004	0.0000	-0.0005	0.2520	0.6401
8 12 2400	2508.30	1198.150	-0.0370	0.0085	0.0006	0.0009	0.0003	0.0000	-0.0005	0.3216	0.8168
8 13 2400	2506.88	1198.121	-0.0290	0.0093	0.0006	0.0009	0.0002	0.0000	-0.0005	0.2148	0.5456
8 14 2400	2504.98	1198.082	-0.0390	0.0087	0.0006	0.0008	0.0001	0.0044	-0.0005	0.3948	1.0028
8 15 2400	2504.03	1198.059	-0.0230	0.0089	0.0006	0.0008	0.0003	0.0000	-0.0005	0.1500	0.3810
8 16 1000	2503.56	1198.046	-0.0130	0.0038	0.0002	0.0004	0.0001	0.0000	-0.0005	0.0984	0.2499
TOTALS			-0.1930	0.0621	0.0041	0.0063	0.0028	0.0169	-0.0035	1.6044	4.0750

TS PERIOD 11 10.00 08/16/65 TO 07.00 08/23/65

DATE TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	WITHDRAWALS SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
8 16 1000	2503.56	1198.040									
8 16 2400	2502.13	1198.023	-0.0230	0.0053	0.0003	0.0005	0.0002	0.0000	0.0006	0.2124	0.5395
8 17 2400	2500.71	1197.993	-0.0300	0.0087	0.0006	0.0008	0.0002	0.0000	0.0006	0.2484	0.6309
8 18 2400	2499.76	1197.967	-0.0260	0.0089	0.0006	0.0007	0.0002	0.0000	0.0006	0.1992	0.5059
8 19 2400	2499.29	1197.955	-0.0120	0.0091	0.0006	0.0007	0.0002	0.0120	0.0006	0.1728	0.4389
8 20 2400	2498.34	1197.944	-0.0110	0.0088	0.0006	0.0009	0.0000	0.0120	0.0006	0.1596	0.4054
8 21 2400	2497.39	1197.924	-0.0200	0.0095	0.0005	0.0008	0.0000	0.0000	0.0006	0.1176	0.2987
8 22 2400	2496.44	1197.895	-0.0290	0.0090	0.0009	0.0008	0.0002	0.0000	0.0007	0.2304	0.5852
8 23 700	2495.96	1197.885	-0.0100	0.0026	0.0002	0.0002	0.0001	0.0006	0.0006	0.0996	0.2530
TOTALS			-0.1610	0.0619	0.0043	0.0054	0.0011	0.0246	0.0049	1.4400	3.6575

TS PERIOD 12 07.00 08/23/65 TO 07.00 08/31/65

DATE TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	WITHDRAWALS SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
8 23 700	2495.96	1197.885									
8 23 2400	2495.49	1197.875	-0.0100	0.0064	0.0005	0.0006	0.0001	0.0000	-0.0005	0.0252	0.0640
8 24 2400	2494.07	1197.845	-0.0300	0.0095	0.0004	0.0008	0.0002	0.0000	-0.0005	0.2280	0.5791
8 25 2400	2492.64	1197.816	-0.0290	0.0091	0.0006	0.0008	0.0002	0.0000	-0.0005	0.2184	0.5547
8 26 2400	2490.27	1197.770	-0.0460	0.0091	0.0005	0.0008	0.0002	0.0000	-0.0005	0.4236	1.0759
8 27 2400	2489.79	1197.757	-0.0130	0.0149	0.0008	0.0008	0.0001	0.0126	-0.0004	0.1056	0.2682
8 28 2400	2488.85	1197.744	-0.0130	0.0090	0.0000	0.0009	0.0000	0.0126	-0.0004	0.1836	0.4663
8 29 2400	2487.42	1197.708	-0.0360	0.0090	0.0003	0.0008	0.0002	0.0000	-0.0005	0.3072	0.7803
8 30 2400	2485.05	1197.662	-0.0460	0.0090	0.0005	0.0007	0.0002	0.0000	-0.0005	0.4260	1.0820
8 31 700	2485.05	1197.655	-0.0070	0.0026	0.0002	0.0002	0.0001	0.0054	-0.0005	0.1080	0.2743
TOTALS			-0.2300	0.0786	0.0038	0.0064	0.0013	0.0306	-0.0043	2.0256	5.1448

TABLE XVI (Continued)

TS PERIOD 13 08.00 09/01/65 TO 07.30 09/06/65

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
9 1	800	2485.52	1197.668									
9 1	2400	2484.57	1197.645	-0.0230	0.0059	0.0000	0.0008	0.0001	0.0000	-0.0002	0.1944	0.4938
9 2	2400	2482.68	1197.606	-0.0390	0.0000	0.0003	0.0011	0.0002	0.0000	-0.0002	0.4512	1.1460
9 3	2400	2483.15	1197.606	-0.0010	0.0000	0.0003	0.0011	0.0002	0.0186	-0.0002	0.2184	0.5547
9 4	2400	2482.20	1197.603	-0.0020	0.0000	0.0000	0.0010	0.0000	0.0187	-0.0002	0.2340	0.5943
9 5	730	2482.20	1197.596	-0.0070	0.0000	0.0001	0.0003	0.0001	0.0000	-0.0002	0.0780	0.1981
9 5	2400	2481.73	1197.586	-0.0100	0.0000	0.0002	0.0008	0.0001	0.0000	-0.0002	0.1068	0.2713
9 6	730	2482.25	1197.583	-0.0030	0.0000	0.0001	0.0003	0.0001	0.0000	-0.0002	0.0300	0.0762
TOTALS				-0.0850	0.0059	0.0010	0.0054	0.0008	0.0373	-0.0014	1.3128	3.3344

TS PERIOD 14 07.30 09/06/65 TO 07.00 09/10/65

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
9 6	730	2482.25	1197.583									
9 6	2400	2482.25	1197.576	-0.0070	0.0000	0.0002	0.0007	0.0001	0.0000	0.0008	0.0840	0.2134
9 7	2400	2480.78	1197.567	-0.0090	0.0000	0.0006	0.0008	0.0002	0.0000	0.0000	0.0936	0.2377
9 8	900	2480.30	1197.560	-0.0070	0.0000	0.0003	0.0003	0.0001	0.0000	0.0008	0.0876	0.2225
9 8	2400	2479.83	1197.553	-0.0070	0.0000	0.0005	0.0005	0.0001	0.0000	0.0008	0.0828	0.2103
9 9	2400	2478.88	1197.527	-0.0260	0.0000	0.0008	0.0007	0.0002	0.0000	0.0008	0.3060	0.7772
9 10	700	2478.40	1197.521	-0.0060	0.0000	0.0003	0.0002	0.0000	0.0000	0.0008	0.0756	0.1920
TOTALS				-0.0620	0.0000	0.0027	0.0032	0.0007	0.0000	0.0040	0.7296	1.8531

TS PERIOD 15 07.00 09/10/65 TO 12.00 09/16/65

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
9 10	700	2478.40	1197.521									
9 10	2400	2476.98	1197.494	-0.0270	0.0000	0.0009	0.0005	0.0000	0.0000	-0.0024	0.2796	0.7102
9 11	2400	2476.51	1197.475	-0.0190	0.0000	0.0003	0.0007	0.0000	0.0000	-0.0024	0.1872	0.4755
9 12	2400	2475.09	1197.448	-0.0270	0.0000	0.0009	0.0007	0.0002	0.0000	-0.0023	0.2796	0.7102
9 13	2400	2473.66	1197.416	-0.0320	0.0000	0.0005	0.0007	0.0002	0.0000	-0.0023	0.3444	0.8747
9 14	2400	2471.29	1197.370	-0.0460	0.0097	0.0008	0.0007	0.0001	0.0031	-0.0024	0.4272	1.0850
9 15	2400	2468.91	1197.317	-0.0530	0.0175	0.0004	0.0008	0.0000	0.0000	-0.0023	0.3840	0.9753
9 16	1200	2467.01	1197.284	-0.0330	0.0088	0.0005	0.0004	0.0000	0.0000	-0.0023	0.2508	0.6370
TOTALS				-0.2370	0.0360	0.0043	0.0045	0.0005	0.0031	-0.0164	2.1528	5.4679

TS PERIOD 16 13.00 09/24/65 TO 09.00 10/02/65

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
9 24	1300	2562.41	1199.289									
9 24	2400	2561.93	1199.276	-0.0130	0.0000	0.0000	0.0005	0.0008	0.0000	-0.0015	0.1416	0.3596
9 25	2400	2560.51	1199.246	-0.0300	0.0000	0.0001	0.0011	0.0013	0.0002	-0.0015	0.3456	0.8778
9 26	2400	2559.56	1199.233	-0.0130	0.0000	0.0001	0.0011	0.0011	0.0000	-0.0015	0.1368	0.3475
9 27	2400	2558.61	1199.213	-0.0200	0.0000	0.0001	0.0010	0.0005	0.0000	-0.0014	0.2160	0.5486
9 28	2400	2557.66	1199.191	-0.0220	0.0000	0.0005	0.0010	0.0002	0.0000	-0.0014	0.2316	0.5882
9 29	2400	2556.71	1199.158	-0.0330	0.0000	0.0003	0.0009	0.0001	0.0038	-0.0015	0.4104	1.0424
9 30	2400	2554.81	1199.125	-0.0330	0.0000	0.0004	0.0009	0.0000	0.0000	-0.0014	0.3636	0.9235
10 1	2400	2552.92	1199.092	-0.0330	0.0000	0.0003	0.0009	0.0002	0.0000	-0.0014	0.3672	0.9327
10 2	900	2552.44	1199.082	-0.0100	0.0000	0.0001	0.0003	0.0001	0.0000	-0.0014	0.0996	0.2530
TOTALS				-0.2070	0.0000	0.0013	0.0077	0.0043	0.0040	-0.0130	2.3124	5.8733

TS PERIOD 17 09.00 10/02/65 TO 07.30 10/10/65

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
10 2	900	2552.44	1199.082									
10 2	2400	2552.44	1199.076	-0.0060	0.0000	0.0002	0.0006	0.0001	0.0000	-0.0005	0.0576	0.1463
10 3	2400	2551.49	1199.063	-0.0130	0.0000	0.0002	0.0008	0.0002	0.0000	-0.0005	0.1404	0.3566
10 4	2400	2551.02	1199.049	-0.0140	0.0000	0.0001	0.0011	0.0001	0.0000	-0.0005	0.1488	0.3779
10 5	2400	2550.54	1199.040	-0.0090	0.0000	0.0001	0.0018	0.0000	0.0004	-0.0006	0.0828	0.2103
10 6	2400	2550.07	1199.030	-0.0100	0.0000	0.0003	0.0008	0.0002	0.0000	-0.0005	0.1032	0.2621
10 7	2400	2549.59	1199.020	-0.0100	0.0000	0.0003	0.0019	0.0002	0.0000	-0.0005	0.0900	0.2286
10 8	2400	2549.12	1199.010	-0.0100	0.0000	0.0004	0.0008	0.0002	0.0000	-0.0005	0.1020	0.2591
10 9	2400	2548.17	1198.994	-0.0160	0.0000	0.0003	0.0010	0.0001	0.0000	-0.0006	0.1704	0.4328
10 10	730	2548.17	1198.990	-0.0040	0.0000	0.0001	0.0002	0.0000	0.0000	-0.0005	0.0384	0.0975
TOTALS				-0.0920	0.0000	0.0020	0.0090	0.0011	0.0004	-0.0047	0.9336	2.3713

TS PERIOD 18 07.30 10/10/65 TO 09.00 10/23/65

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
10 10	730	2548.17	1198.990									
10 10	2400	2547.70	1198.977	-0.0130	0.0000	0.0003	0.0005	0.0000	0.0000	-0.0006	0.1392	0.3536
10 11	2400	2545.80	1198.938	-0.0390	0.0000	0.0003	0.0008	0.0002	0.0000	-0.0006	0.4500	1.1430
10 12	2400	2545.32	1198.925	-0.0130	0.0000	0.0002	0.0008	0.0002	0.0012	-0.0007	0.1524	0.3871
10 13	2400	2544.37	1198.908	-0.0170	0.0000	0.0002	0.0008	0.0001	0.0000	-0.0006	0.1860	0.4724
10 14	2400	2543.90	1198.902	-0.0060	0.0000	0.0003	0.0008	0.0001	0.0000	-0.0006	0.0528	0.1341
10 15	2400	2544.37	1198.908	0.0060	0.0000	0.0001	0.0008	0.0002	0.0175	-0.0007	0.1212	0.3078
10 16	2400	2544.37	1198.905	-0.0030	0.0000	0.0000	0.0009	0.0003	0.0000	-0.0006	0.0216	0.0549
10 17	2400	2543.90	1198.895	-0.0100	0.0000	0.0001	0.0008	0.0002	0.0000	-0.0006	0.1044	0.2652
10 18	2400	2545.80	1198.941	0.0460	0.0000	0.0000	0.0034	0.0004	0.0600	-0.0007	0.1236	0.3139
10 19	2400	2545.32	1198.928	-0.0130	0.0000	0.0000	0.0018	0.0002	0.0000	-0.0006	0.1296	0.3292
10 20	2400	2544.37	1198.905	-0.0230	0.0000	0.0000	0.0020	0.0003	0.0000	-0.0007	0.2472	0.6279
10 21	2400	2542.48	1198.866	-0.0390	0.0000	0.0000	0.0012	0.0002	0.0000	-0.0006	0.4488	1.1399
10 22	2400	2541.05	1198.843	-0.0230	0.0000	0.0001	0.0009	0.0001	0.0000	-0.0006	0.2580	0.6553
10 23	900	2541.05	1198.836	-0.0070	0.0000	0.0000	0.0003	0.0000	0.0000	-0.0006	0.0732	0.1859
TOTALS				-0.1540	0.0000	0.0016	0.0158	0.0025	0.0787	-0.0088	2.5080	6.3701

TABLE XVII

DAILY WATER BUDGET, 1966

TS PERIOD 1 8.00 06/14/66 TO 7.50 06/21/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	WITHDRAWALS SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
06/14	0800	2412.10	1196.123									
06/14	2400	2410.07	1196.080	-0.0427	0.0266	0.0004	0.0002	0.0002	0.0000	0.0000	0.1886	0.4791
06/15	2400	2410.28	1196.085	0.0044	0.0381	0.0004	0.0003	0.0005	0.0650	0.0000	0.2677	0.6801
06/16	2400	2415.83	1196.202	0.1170	0.0221	0.0004	0.0009	0.0046	0.1450	0.0000	0.1096	0.2784
06/17	2400	2414.43	1196.172	-0.0295	0.0148	0.0000	0.0006	0.0006	0.0025	0.0000	0.2058	0.5227
06/18	2400	2412.88	1196.139	-0.0328	0.0181	0.0001	0.0006	0.0005	0.0000	0.0001	0.1746	0.4435
06/19	2400	2411.53	1196.111	-0.0284	0.0139	0.0001	0.0006	0.0004	0.0000	0.0001	0.1714	0.4353
06/20	2400	2409.19	1196.062	-0.0492	0.0258	0.0002	0.0006	0.0004	0.0000	0.0001	0.2774	0.7046
06/21	0730	2408.57	1196.048	-0.0131	0.0085	0.0009	0.0004	0.0001	0.0000	0.0000	0.0408	0.1038
TOTALS				-0.0744	0.1680	0.0026	0.0042	0.0073	0.2125	0.0003	1.4360	3.6476

TS PERIOD 2 7.50 6/21/66 TO 8.00 6/28/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	WITHDRAWALS SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
06/21	0730	2408.57	1196.048									
06/21	2400	2406.86	1196.012	-0.0361	0.0188	0.0004	0.0008	0.0001	0.0000	0.0007	0.2031	0.5159
06/22	2400	2403.95	1195.951	-0.0612	0.0285	0.0005	0.0012	0.0000	0.0000	0.0011	0.3856	0.9794
06/23	2400	2401.30	1195.895	-0.0558	0.0327	0.0008	0.0011	0.0003	0.0000	0.0011	0.2711	0.6887
06/24	2400	2398.19	1195.830	-0.0656	0.0308	0.0004	0.0008	0.0003	0.0000	0.0011	0.4210	1.0693
06/25	2400	2395.59	1195.775	-0.0547	0.0352	0.0009	0.0009	0.0003	0.0000	0.0011	0.2287	0.5810
06/26	2400	2393.52	1195.731	-0.0437	0.0293	0.0007	0.0010	0.0002	0.0000	0.0011	0.1685	0.4279
06/27	2400	2390.45	1195.667	-0.0645	0.0410	0.0008	0.0010	0.0000	0.0000	0.0011	0.2741	0.6962
06/28	0800	2389.68	1195.650	-0.0164	0.0137	0.0009	0.0003	0.0001	0.0000	0.0004	0.0237	0.0603
TOTALS				-0.3981	0.2298	0.0054	0.0072	0.0014	0.0000	0.0077	1.9759	5.0187

TS PERIOD 3 8.00 06/28/66 TO 10.50 07/06/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	WITHDRAWALS SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
06/28	0800	2389.68	1195.650									
06/28	2400	2387.60	1195.607	-0.0437	0.0274	0.0007	0.0007	0.0002	0.0000	0.0008	0.1913	0.4859
06/29	2400	2384.95	1195.551	-0.0558	0.0390	0.0008	0.0009	0.0002	0.0000	0.0013	0.1997	0.5073
06/30	2400	2382.62	1195.502	-0.0492	0.0384	0.0007	0.0010	0.0002	0.0000	0.0013	0.1276	0.3242
07/01	2400	2379.76	1195.441	-0.0601	0.0370	0.0012	0.0009	0.0000	0.0000	0.0013	0.2683	0.6814
07/02	2400	2377.38	1195.391	-0.0503	0.0369	0.0009	0.0010	0.0002	0.0000	0.0013	0.1566	0.3977
07/03	2400	2375.04	1195.342	-0.0492	0.0302	0.0006	0.0010	0.0003	0.0000	0.0013	0.2297	0.5835
07/04	2400	2372.50	1195.288	-0.0536	0.0346	0.0007	0.0009	0.0002	0.0000	0.0013	0.2271	0.5768
07/05	2400	2369.17	1195.218	-0.0700	0.0444	0.0011	0.0009	0.0000	0.0000	0.0013	0.2992	0.7599
07/06	1030	2367.62	1195.186	-0.0328	0.0207	0.0011	0.0004	0.0001	0.0000	0.0004	0.1326	0.3367
TOTALS				-0.4648	0.3085	0.0077	0.0075	0.0013	0.0000	0.0103	1.8321	4.6534

TS PERIOD 4 10.50 07/06/66 TO 8.00 07/12/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	WITHDRAWALS SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
07/06	1030	2367.62	1195.186									
07/06	2400	2365.90	1195.149	-0.0361	0.0267	0.0007	0.0005	0.0001	0.0000	0.0007	0.1083	0.2751
07/07	2400	2362.69	1195.082	-0.0678	0.0464	0.0007	0.0009	0.0003	0.0000	0.0010	0.2536	0.6440
07/08	2400	2359.52	1195.015	-0.0667	0.0372	0.0012	0.0009	0.0002	0.0000	0.0010	0.3426	0.8701
07/09	2400	2356.41	1194.949	-0.0656	0.0404	0.0009	0.0003	0.0000	0.0000	0.0009	0.2984	0.7578
07/10	2400	2353.45	1194.887	-0.0623	0.0362	0.0006	0.0003	0.0003	0.0000	0.0009	0.3180	0.8078
07/11	2400	2349.50	1194.804	-0.0831	0.0450	0.0011	0.0003	0.0003	0.0000	0.0010	0.4558	1.1578
07/12	0800	2348.52	1194.783	-0.0208	0.0158	0.0014	0.0001	0.0001	0.0000	0.0003	0.0462	0.1172
TOTALS				-0.4025	0.2477	0.0066	0.0031	0.0011	0.0000	0.0058	1.8228	4.6299

TS PERIOD 5 8.00 07/12/66 TO 10.00 07/25/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	WITHDRAWALS SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
07/12	0800	2348.52	1194.783									
07/12	2400	2345.61	1194.722	-0.0612	0.0317	0.0006	0.0002	0.0001	0.0000	0.0002	0.3488	0.8860
07/13	2400	2349.92	1194.813	0.0908	0.0439	0.0007	0.0002	0.2036	0.0000	0.0003	0.8199	2.0827
07/14	2400	2370.94	1195.256	0.4429	0.0476	0.0010	0.0002	0.5361	0.0000	0.0003	0.5360	1.3615
07/15	2400	2390.66	1195.671	0.4156	0.0411	0.0010	0.0002	0.4790	0.0000	0.0003	0.2574	0.6538
07/16	2400	2410.59	1196.091	0.4199	0.0346	0.0008	0.0003	0.4751	0.0000	0.0002	0.2352	0.5974
07/17	2400	2429.07	1196.480	0.3893	0.0296	0.0008	0.0003	0.4434	0.0000	0.0002	0.2846	0.7229
07/18	2400	2448.69	1196.894	0.4134	0.0480	0.0008	0.0003	0.5034	0.0000	0.0002	0.4932	1.2528
07/19	2400	2468.78	1197.317	0.4232	0.0399	0.0010	0.0002	0.5413	0.0000	0.0003	0.9276	2.3560
07/20	2400	2488.65	1197.736	0.4188	0.0191	0.0011	0.0003	0.4889	0.0108	0.0003	0.7287	1.8510
07/21	2400	2512.89	1198.247	0.5107	0.0138	0.0008	0.0004	0.5838	0.0187	0.0003	0.9249	2.3492
07/22	2400	2538.95	1198.796	0.5490	0.0160	0.0005	0.0003	0.6086	0.0027	0.0003	0.5489	1.3942
07/23	2400	2558.41	1199.206	0.4101	0.0094	0.0004	0.0011	0.3642	0.0565	0.0003	-0.0002	-0.0005
07/24	2400	2565.42	1199.353	0.1476	0.0111	0.0003	0.0004	0.1696	0.0008	0.0003	0.1353	0.3437
07/25	1000	2567.44	1199.396	0.0426	0.0076	-0.0002	0.0002	0.0467	0.0000	0.0002	-0.0394	-0.1001
TOTALS				4.6129	0.3934	0.0095	0.0045	5.4438	0.0896	0.0037	6.2010	15.7505

TS PERIOD 6 10.00 07/25/66 TO 12.50 08/02/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	WITHDRAWALS SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
07/25	1000	2567.44	1199.396									
07/25	2400	2568.12	1199.410	0.0142	0.0106	0.0003	0.0002	0.0380	0.0000	0.0004	0.1570	0.3987
07/26	2400	2567.86	1199.405	-0.0055	0.0204	0.0003	0.0004	0.0433	0.0000	0.0007	0.3402	0.8642
07/27	2400	2565.26	1199.350	-0.0547	0.0273	0.0007	0.0003	0.0009	0.0000	0.0008	0.3358	0.8528
07/28	2400	2563.08	1199.304	-0.0459	0.0303	0.0007	0.0003	0.0005	0.0000	0.0008	0.1905	0.4839
07/29	2400	2561.16	1199.264	-0.0405	0.0271	0.0005	0.0003	0.0018	0.0010	0.0007	0.1925	0.4890
07/30	2400	2561.79	1199.277	0.0131	0.0301	0.0004	0.0003	0.0014	0.0469	0.0007	0.0602	0.1530
07/31	2400	2560.23	1199.244	-0.0328	0.0214	0.0003	0.0006	0.0012	0.0000	0.0007	0.1479	0.3756
08/01	2400	2557.32	1199.183	-0.0612	0.0375	0.0003	0.0003	0.0009	0.0000	0.0007	0.2959	0.7516
08/02	1230	2556.23	1199.160	-0.0230	0.0155	0.0004	0.0002	0.0003	0.0000	0.0004	0.0917	0.2329
TOTALS				-0.2362	0.2202	0.0039	0.0030	0.0881	0.0479	0.0059	1.8117	4.6018

TABLE XVII (Continued)

TS PERIOD 7 9.50 08/03/66 TO 11.50 08/10/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
08/03	0930	2552.91	1199.090									
08/03	2400	2550.99	1199.049	-0.0405	0.0222	0.0002	0.0002	0.0002	0.0000	-0.0001	0.2167	0.5503
08/04	2400	2547.88	1198.984	-0.0656	0.0418	0.0003	0.0003	0.0003	0.0000	-0.0003	0.2778	0.7057
08/05	2400	2545.90	1198.942	-0.0416	0.0245	0.0008	0.0004	0.0006	0.0015	-0.0002	0.2130	0.5411
08/06	2400	2542.89	1198.879	-0.0634	0.0363	0.0004	0.0003	0.0005	0.0006	-0.0003	0.3265	0.8293
08/07	2400	2540.61	1198.831	-0.0481	0.0361	0.0004	0.0003	0.0003	0.0025	-0.0003	0.1654	0.4200
08/08	2400	2537.91	1198.774	-0.0569	0.0408	0.0004	0.0003	0.0001	0.0000	-0.0003	0.1819	0.4620
08/09	2400	2534.80	1198.708	-0.0656	0.0402	0.0006	0.0003	0.0005	0.0000	-0.0002	0.2969	0.7542
08/10	1130	2533.81	1198.687	-0.0208	0.0153	0.0008	0.0002	0.0002	0.0117	-0.0001	0.1960	0.4978
TOTALS				-0.4025	0.2571	0.0039	0.0024	0.0027	0.0162	-0.0018	1.8742	4.7604

TS PERIOD 8 9.50 08/12/66 TO 14.00 08/19/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
08/12	0930	2529.50	1198.597									
08/12	2400	2528.00	1198.565	-0.0317	0.0187	0.0002	0.0005	0.0000	0.0000	0.0001	0.1495	0.3797
08/13	2400	2526.75	1198.539	-0.0262	0.0222	0.0003	0.0010	0.0005	0.0000	0.0002	0.0430	0.1092
08/14	2400	2524.83	1198.498	-0.0405	0.0241	0.0003	0.0009	0.0004	0.0000	0.0002	0.1886	0.4789
08/15	2400	2521.77	1198.434	-0.0645	0.0384	0.0004	0.0009	0.0003	0.0000	0.0002	0.3045	0.7734
08/16	2400	2518.86	1198.372	-0.0613	0.0420	0.0006	0.0008	0.0002	0.0000	0.0002	0.2188	0.5556
08/17	2400	2515.64	1198.305	-0.0678	0.0450	0.0005	0.0009	0.0000	0.0000	0.0002	0.2594	0.6590
08/18	2400	2521.61	1198.430	0.1258	0.0410	0.0006	0.0008	0.0006	0.1725	0.0002	0.0600	0.1524
08/19	1400	2521.66	1198.431	0.0011	0.0109	0.0000	0.0009	0.0003	0.0160	0.0002	0.0439	0.1116
TOTALS				-0.1651	0.2423	0.0029	0.0067	0.0023	0.1885	0.0015	1.2677	3.2200

TS PERIOD 9 14.00 08/19/66 TO 8.00 08/28/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
08/19	1400	2521.66	1198.431									
08/19	2400	2523.12	1198.462	0.0306	0.0078	0.0000	0.0006	0.0342	0.0152	-0.0020	0.1009	0.2563
08/20	2400	2526.91	1198.542	0.0798	0.0165	0.0000	0.0012	0.1139	0.0000	-0.0026	0.1641	0.4167
08/21	2400	2529.19	1198.590	0.0481	0.0123	0.0004	0.0015	0.0698	0.0015	-0.0020	0.0836	0.2123
08/22	2400	2527.01	1198.544	-0.0459	0.0166	0.0002	0.0014	0.0009	0.0000	-0.0020	0.3202	0.8134
08/23	2400	2527.58	1198.556	0.0120	0.0114	0.0001	0.0016	0.0006	0.0515	-0.0020	0.2996	0.7610
08/24	2400	2527.01	1198.544	-0.0120	0.0125	0.0000	0.0014	0.0006	0.0173	-0.0020	0.1676	0.4257
08/25	2400	2525.30	1198.508	-0.0361	0.0143	0.0000	0.0009	0.0002	0.0000	-0.0020	0.2297	0.5835
08/26	2400	2523.27	1198.465	-0.0426	0.0148	0.0001	0.0011	0.0001	0.0000	-0.0020	0.2974	0.7553
08/27	2400	2521.77	1198.434	-0.0317	0.0089	0.0003	0.0010	0.0004	0.0000	-0.0020	0.2390	0.6071
08/28	0800	2521.20	1198.422	-0.0121	0.0039	0.0002	0.0003	0.0001	0.0000	-0.0010	0.0815	0.2070
TOTALS				-0.0099	0.1189	0.0013	0.0111	0.2210	0.0854	-0.0196	1.9836	5.0383

TS PERIOD 10 8.00 08/28/66 TO 17.00 09/03/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
08/28	0800	2521.20	1198.422									
08/28	2400	2520.57	1198.408	-0.0131	0.0077	0.0001	0.0007	0.0003	0.0000	0.0006	0.0660	0.1676
08/29	2400	2518.97	1198.375	-0.0339	0.0163	0.0001	0.0009	0.0002	0.0000	0.0011	0.2145	0.5448
08/30	2400	2518.03	1198.355	-0.0197	0.0141	0.0005	0.0015	0.0000	0.0000	0.0011	0.0562	0.1427
08/31	2400	2519.64	1198.389	0.0339	0.0114	0.0003	0.0013	0.0005	0.0560	0.0011	0.1293	0.3285
09/01	2400	2518.45	1198.364	-0.0251	0.0108	0.0001	0.0008	0.0003	0.0008	0.0011	0.1882	0.4782
09/02	2400	2517.25	1198.338	-0.0252	0.0153	0.0002	0.0009	0.0003	0.0000	0.0011	0.1225	0.3111
09/03	1700	2517.05	1198.334	-0.0044	0.0068	0.0001	0.0006	0.0003	0.0073	0.0006	0.0601	0.1527
TOTALS				-0.0875	0.0825	0.0013	0.0067	0.0019	0.0642	0.0067	0.8368	2.1255

TS PERIOD 11 17.30 09/04/66 TO 17.00 09/12/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
09/04	1730	2518.45	1198.364									
09/04	2400	2517.93	1198.353	-0.0109	0.0024	0.0000	0.0003	0.0002	0.0000	-0.0003	0.0969	0.2462
09/05	2400	2517.36	1198.341	-0.0120	0.0108	0.0000	0.0009	0.0005	0.0000	-0.0007	0.0020	0.0050
09/06	2400	2515.18	1198.295	-0.0459	0.0167	0.0002	0.0009	0.0005	0.0000	-0.0007	0.3346	0.8499
09/07	2400	2513.78	1198.265	-0.0295	0.0146	0.0001	0.0015	0.0002	0.0000	-0.0007	0.1539	0.3909
09/08	2400	2512.37	1198.236	-0.0295	0.0120	0.0002	0.0013	0.0001	0.0000	-0.0007	0.1850	0.4698
09/09	2400	2511.08	1198.208	-0.0273	0.0139	0.0001	0.0009	0.0004	0.0000	-0.0007	0.1462	0.3714
09/10	2400	2509.88	1198.183	-0.0252	0.0140	0.0001	0.0011	0.0004	0.0000	-0.0008	0.1145	0.2908
09/11	2400	2508.90	1198.162	-0.0208	0.0119	0.0001	0.0006	0.0004	0.0000	-0.0008	0.0929	0.2359
09/12	1700	2508.01	1198.144	-0.0186	0.0086	0.0001	0.0005	0.0002	0.0000	-0.0005	0.1073	0.2725
TOTALS				-0.2198	0.1050	0.0009	0.0080	0.0028	0.0000	-0.0059	1.2332	3.1324

TS PERIOD 12 17.00 09/12/66 TO 16.00 09/21/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
09/12	1700	2508.01	1198.144									
09/12	2400	2507.75	1198.138	-0.0055	0.0036	0.0001	0.0002	0.0001	0.0000	0.0006	0.0275	0.0698
09/13	2400	2514.66	1198.284	0.1454	0.0111	0.0001	0.0011	0.0009	0.1469	0.0015	-0.1016	-0.2580
09/14	2400	2514.19	1198.274	-0.0099	0.0087	0.0000	0.0014	0.0021	0.0125	0.0015	0.1905	0.4840
09/15	2400	2528.26	1198.570	0.2964	0.0114	0.0000	0.0012	0.3296	0.0000	0.0015	0.2659	0.6753
09/16	2400	2536.56	1198.745	0.1750	0.0101	0.0000	0.0012	0.1684	0.0181	0.0015	0.0209	0.0531
09/17	2400	2540.82	1198.835	0.0897	0.0128	0.0000	0.0012	0.1109	0.0154	0.0015	0.2910	0.7391
09/18	2400	2539.78	1198.813	-0.0219	0.0174	0.0000	0.0011	0.0069	0.0000	0.0015	0.1406	0.3571
09/19	2400	2537.75	1198.770	-0.0427	0.0154	0.0000	0.0011	0.0006	0.0000	0.0015	0.3394	0.8622
09/20	2400	2536.25	1198.739	-0.0317	0.0128	0.0001	0.0012	0.0006	0.0000	0.0015	0.2370	0.6020
09/21	1600	2535.57	1198.724	-0.0142	0.0125	0.0001	0.0007	0.0006	0.0000	0.0012	0.0318	0.0809
TOTALS				0.5807	0.1157	0.0003	0.0105	0.6207	0.1929	0.0138	1.4431	3.6655

TABLE XVII (Continued)

TS PERIOD 13   16.00 09/21/66 TO 15.30 09/29/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
09/21	1600	2535.57	1198.724									
09/21	2400	2535.00	1198.712	-0.0120	0.0062	0.0000	0.0004	0.0003	0.0000	-0.0002	0.0661	0.1680
09/22	2400	2532.82	1198.667	-0.0459	0.0201	0.0004	0.0010	0.0007	0.0000	-0.0005	0.2958	0.7513
09/23	2400	2531.58	1198.640	-0.0262	0.0220	0.0003	0.0011	0.0007	0.0000	-0.0006	0.0349	0.0886
09/24	2400	2529.40	1198.594	-0.0459	0.0189	0.0003	0.0011	0.0006	0.0000	-0.0005	0.3104	0.7883
09/25	2400	2527.68	1198.558	-0.0361	0.0197	0.0005	0.0013	0.0006	0.0000	-0.0006	0.1756	0.4459
09/26	2400	2526.18	1198.527	-0.0317	0.0265	-0.0000	0.0008	0.0004	0.0000	-0.0005	0.0520	0.1321
09/27	2400	2528.57	1198.577	0.0503	0.0165	0.0008	0.0013	0.0020	0.0923	-0.0006	0.2972	0.7549
09/28	2400	2527.27	1198.549	-0.0274	0.0190	0.0000	0.0010	0.0008	0.0000	-0.0005	0.0912	0.2317
09/29	1530	2526.28	1198.529	-0.0208	0.0131	0.0002	0.0011	0.0004	0.0000	-0.0004	0.0773	0.1964
TOTALS				-0.1958	0.1620	0.0024	0.0090	0.0065	0.0923	-0.0044	1.4005	3.5573

TS PERIOD 14   15.30 09/29/66 TO 15.00 10/06/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
09/29	1530	2526.28	1198.529									
09/29	2400	2525.51	1198.512	-0.0164	0.0074	0.0001	0.0006	0.0002	0.0000	-0.0010	0.0895	0.2274
09/30	2400	2522.81	1198.455	-0.0569	0.0172	0.0001	0.0016	0.0002	0.0008	-0.0028	0.4344	1.1033
10/01	2400	2520.99	1198.417	-0.0383	0.0176	0.0002	0.0015	0.0000	0.0000	-0.0029	0.1922	0.4883
10/02	2400	2517.56	1198.345	-0.0722	0.0139	0.0002	0.0009	0.0002	0.0000	-0.0028	0.6560	1.6663
10/03	2400	2515.70	1198.306	-0.0394	0.0227	0.0003	0.0008	0.0003	0.0000	-0.0028	0.1572	0.3994
10/04	2400	2512.89	1198.247	-0.0591	0.0189	0.0005	0.0013	0.0002	0.0000	-0.0028	0.4283	1.0879
10/05	2400	2511.54	1198.218	-0.0284	0.0202	0.0003	0.0008	0.0005	0.0000	-0.0028	0.0575	0.1460
10/06	1500	2510.56	1198.197	-0.0208	0.0137	0.0003	0.0007	0.0003	0.0000	-0.0020	0.0523	0.1329
TOTALS				-0.3314	0.1317	0.0019	0.0083	0.0019	0.0008	-0.0199	2.0675	5.2515

TS PERIOD 15   15.00 10/06/66 TO 11.30 10/15/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
10/06	1500	2510.51	1198.196									
10/06	2400	2509.73	1198.180	-0.0164	0.0082	0.0002	0.0004	0.0002	0.0000	-0.0003	0.0892	0.2267
10/07	2400	2507.75	1198.138	-0.0415	0.0216	0.0001	0.0010	0.0005	0.0000	-0.0006	0.2249	0.5713
10/08	2400	2506.15	1198.104	-0.0339	0.0186	0.0005	0.0010	0.0005	0.0000	-0.0006	0.1637	0.4159
10/09	2400	2504.74	1198.075	-0.0295	0.0191	0.0003	0.0015	0.0002	0.0000	-0.0006	0.0996	0.2530
10/10	2400	2502.77	1198.033	-0.0415	0.0227	0.0004	0.0015	0.0001	0.0000	-0.0006	0.1968	0.4998
10/11	2400	2500.80	1197.992	-0.0416	0.0229	0.0006	0.0008	0.0005	0.0000	-0.0007	0.2048	0.5202
10/12	2400	2499.29	1197.960	-0.0317	0.0265	0.0005	0.0013	0.0005	0.0000	-0.0007	0.0382	0.0969
10/13	2400	2498.36	1197.940	-0.0197	0.0234	0.0005	0.0014	0.0002	0.0000	-0.0007	-0.0729	-0.1851
10/14	2400	2496.03	1197.891	-0.0492	0.0198	0.0005	0.0011	0.0001	0.0000	-0.0007	0.3260	0.8280
10/15	1130	2493.95	1197.847	-0.0437	0.0089	0.0005	0.0005	0.0001	0.0000	-0.0003	0.4040	1.0262
TOTALS				-0.3489	0.1918	0.0040	0.0106	0.0029	0.0000	-0.0058	1.6743	4.2528

TS PERIOD 16   16.00 10/15/66 TO 16.00 10/22/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
10/15	1600	2493.01	1197.828									
10/16	1600	2491.46	1197.795	-0.0328	0.0184	0.0001	0.0012	0.0004	0.0000	-0.0018	0.1401	0.3558
10/18	1600	2490.26	1197.770	-0.0251	0.0346	0.0002	0.0022	0.0010	0.0308	-0.0037	0.1949	0.4951
10/20	1600	2485.23	1197.664	-0.1061	0.0357	0.0001	0.0026	0.0003	0.0000	-0.0036	0.7726	1.9625
10/22	1600	2480.04	1197.554	-0.1094	0.0373	0.0005	0.0018	0.0008	0.0000	-0.0036	0.8035	2.0409
TOTALS				-0.2734	0.1261	0.0009	0.0078	0.0025	0.0308	-0.0127	1.9111	4.8542

TS PERIOD 17   16.00 10/22/66 TO 16.00 10/29/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
10/22	1600	2480.04	1197.554									
10/23	1600	2478.79	1197.528	-0.0262	0.0149	0.0002	0.0010	0.0004	0.0000	-0.0004	0.1213	0.3082
10/25	1600	2475.21	1197.453	-0.0755	0.0440	0.0008	0.0019	0.0005	0.0000	-0.0006	0.3440	0.8738
10/27	1600	2472.41	1197.394	-0.0591	0.0470	0.0008	0.0013	0.0007	0.0000	-0.0006	0.1210	0.3075
10/29	1600	2469.24	1197.327	-0.0667	0.0424	0.0010	0.0021	0.0006	0.0000	-0.0007	0.2537	0.6444
TOTALS				-0.2275	0.1482	0.0028	0.0063	0.0022	0.0000	-0.0023	0.8401	2.1339

TS PERIOD 18   16.00 10/29/66 TO 16.00 11/05/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
10/29	1600	2469.24	1197.327									
11/01	1600	2464.10	1197.219	-0.1082	0.0573	0.0012	0.0024	0.0005	0.0000	-0.0026	0.5426	1.3783
11/03	1600	2459.80	1197.128	-0.0908	0.0416	0.0003	0.0020	0.0002	0.0000	-0.0018	0.5436	1.3809
11/05	1600	2457.20	1197.073	-0.0547	0.0345	0.0005	0.0015	0.0006	0.0000	-0.0018	0.2049	0.5205
TOTALS				-0.2537	0.1333	0.0020	0.0060	0.0014	0.0000	-0.0062	1.2912	3.2797

TS PERIOD 19   16.00 11/05/66 TO 16.00 11/12/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
11/05	1600	2457.20	1197.073									
11/06	1600	2456.37	1197.056	-0.0175	0.0176	0.0001	0.0008	0.0002	0.0000	-0.0005	-0.0144	-0.0366
11/08	1600	2453.88	1197.003	-0.0525	0.0443	0.0005	0.0017	0.0003	0.0000	-0.0011	0.0613	0.1558
11/11	1600	2449.26	1196.906	-0.0973	0.0556	0.0009	0.0037	0.0011	0.0073	-0.0016	0.5269	1.3383
11/12	1600	2447.55	1196.870	-0.0361	0.0197	0.0001	0.0010	0.0000	0.0000	-0.0005	0.1781	0.4525
TOTALS				-0.2034	0.1372	0.0016	0.0072	0.0016	0.0073	-0.0037	0.7519	1.9099

TABLE XVII (Continued)

TS PERIOD 20 16.00 11/12/66 TO 16.00 11/19/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	WITHDRAWALS SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
11/12	1600	2447.55	1196.870									
11/16	1600	2441.94	1196.752	-0.1181	0.0820	0.0013	0.0044	0.0008	0.0000	0.0005	0.3800	0.9653
11/19	1600	2437.53	1196.659	-0.0930	0.0634	0.0006	0.0031	0.0000	0.0000	0.0003	0.3138	0.7971
TOTALS				-0.2111	0.1454	0.0019	0.0076	0.0008	0.0000	0.0008	0.6938	1.7624

TS PERIOD 21 16.00 11/19/66 TO 16.00 11/27/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	WITHDRAWALS SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
11/19	1600	2437.53	1196.659									
11/20	1600	2436.28	1196.632	-0.0262	0.0176	0.0002	0.0008	0.0003	0.0000	0.0003	0.0990	0.2515
11/27	1600	2429.33	1196.486	-0.1465	0.1399	0.0014	0.0068	0.0562	0.0242	0.0019	0.9679	2.4585
TOTALS				-0.1728	0.1576	0.0017	0.0076	0.0566	0.0242	0.0022	1.0669	2.7100

TS PERIOD 22 16.00 11/27/66 TO 16.00 12/04/66

DATE	TIME	LAKE AREA ACRES	LAKE STAGE FEET	STAGE CHANGE FEET	WITHDRAWALS PLANT FEET	WITHDRAWALS IRRIGATION FEET	WITHDRAWALS SEEPAGE FEET	INFLOW FEET	RAIN FEET	THERMAL EXPANSION FEET	EVAPORATION INCHES	EVAPORATION CENTIMETERS
11/27	1600	2429.33	1196.486									
12/04	1600	2417.03	1196.227	-0.2592	0.1218	0.0009	0.0092	0.0007	0.0017	-0.0127	1.4038	3.5656
TOTALS				-0.2592	0.1218	0.0009	0.0092	0.0007	0.0017	-0.0127	1.4038	3.5656

APPENDIX B

DAILY ENERGY BUDGET, 1966

TABLE XVIII

DAILY ENERGY BUDGET, 1966

ENERGY BUDGET TSP 1 8.00 06/14/66 TO 7.50 06/21/66

DATE	QS	QR	QA	QAR	QBS	QN	TO	TA	EO	EA	DE	RH	R
			GM*CAL/CM**2				CENTIGRADE			MILLIBARS			
06/14	648.1	42.3	583.3	17.5	599.9	571.7	25.08	29.50	31.82	12.96	18.86	31.44	-0.1393
06/15	567.9	36.4	839.4	25.2	878.3	467.4	23.36	27.03	28.71	16.51	12.20	46.23	-0.1773
06/16	632.8	38.4	755.2	22.7	878.3	448.6	23.37	21.84	28.72	16.52	12.21	63.12	0.0744
06/17	306.5	25.6	826.4	24.8	881.7	200.8	23.65	20.54	29.22	13.04	16.17	53.98	0.1142
06/18	631.7	38.3	800.9	24.0	884.6	485.7	23.89	22.27	29.64	15.47	14.17	57.56	0.0679
06/19	647.7	38.8	792.4	23.8	886.6	491.0	24.06	24.10	29.94	16.42	13.52	54.72	-0.0015
06/20	656.8	42.5	806.9	24.2	876.5	520.4	23.23	25.02	28.47	16.67	11.80	52.57	-0.0903
06/21	26.7	3.6	223.9	6.7	275.8	-35.5	23.75	21.00	29.38	12.20	17.18	49.09	0.0950
TOTAL	4118.1	266.0	5628.5	168.9	6161.7	3150.2							
AVG	590.8	38.2	807.4	24.2	883.9	451.9	23.77	23.96	29.42	15.36	14.06	52.29	-0.0109

	QE	QO	QV	E(CM)	E(IN)	E(AC-FT)	FINAL STAGE
TOTAL	2969.4	102.1	9.9	5.1082	2.0111	404.26	1196.13
AVG	426.0	14.6	1.4	0.7328	0.2885	57.99	

ENERGY BUDGET TSP 2 7.50 6/21/66 TO 8.00 6/28/66

DATE	QS	QR	QA	QAR	QBS	QN	TO	TA	EO	EA	DE	RH	R
			GM*CAL/CM**2				CENTIGRADE			MILLIBARS			
06/21	654.9	42.5	593.2	17.8	608.9	578.9	23.99	27.71	29.81	16.02	13.79	43.10	-0.1604
06/22	676.7	43.0	822.1	24.7	883.9	547.2	23.84	25.76	29.55	17.28	12.28	52.14	-0.0923
06/23	666.9	42.8	817.9	24.5	881.9	535.6	23.67	26.10	29.25	19.67	9.58	58.19	-0.1496
06/24	656.0	39.0	870.3	26.1	883.3	577.8	23.80	26.95	29.47	22.40	7.06	63.05	-0.2632
06/25	697.5	43.6	876.1	26.3	889.2	614.5	24.29	27.87	30.35	23.24	7.11	61.97	-0.2982
06/26	598.8	37.4	909.7	27.3	893.5	550.3	24.64	28.28	31.00	22.67	8.33	59.01	-0.2598
06/27	681.6	43.2	868.7	26.1	893.9	587.1	24.68	27.87	31.08	18.01	13.07	48.00	-0.1447
06/28	41.1	5.1	250.9	7.5	297.0	-17.7	24.44	23.76	30.63	16.79	13.85	57.10	0.0293
TOTAL	4673.6	296.6	6008.8	180.3	6231.6	3973.9							
AVG	665.7	42.2	855.9	25.7	887.6	566.0	24.15	27.03	30.11	19.92	10.19	55.69	-0.1863

	QE	QO	QV	E(CM)	E(IN)	E(AC-FT)	FINAL STAGE
TOTAL	3795.6	559.9	-167.6	6.5344	2.5726	514.23	1195.84
AVG	540.6	79.7	-23.9	0.9307	0.3664	73.24	

ENERGY BUDGET TSP 3 8.00 06/28/66 TO 10.50 07/06/66

DATE	QS	QR	QA	QAR	QBS	QN	TO	TA	EO	EA	DE	RH	R
			GM*CAL/CM**2				CENTIGRADE			MILLIBARS			
06/28	609.2	41.2	627.5	18.8	595.7	581.0	24.65	24.72	31.01	17.95	13.05	57.64	-0.0035
06/29	660.7	42.6	847.5	25.4	898.7	541.5	25.07	28.27	31.80	15.65	16.15	40.76	-0.1173
06/30	646.7	38.8	857.5	25.7	910.8	528.9	26.06	28.99	33.72	14.33	19.39	35.81	-0.0890
07/01	628.7	38.3	886.9	26.6	921.8	528.9	26.95	29.55	35.55	18.61	16.94	45.01	-0.0903
07/02	658.2	42.5	874.6	26.2	917.0	547.1	26.58	29.78	34.78	22.40	12.38	53.47	-0.1520
07/03	656.4	42.5	896.7	26.9	926.0	557.6	27.28	30.04	36.25	25.14	11.10	59.11	-0.1463
07/04	657.8	42.5	912.2	27.4	924.9	575.2	27.21	30.07	36.09	24.52	11.57	57.55	-0.1457
07/05	681.2	43.2	873.3	26.2	926.1	559.1	27.30	30.50	36.29	20.76	15.52	47.55	-0.1213
07/06	144.3	14.7	373.4	11.2	401.6	90.1	26.69	27.28	35.00	23.01	11.99	63.50	-0.0290
TOTAL	5343.1	346.3	7149.7	214.5	7422.6	4509.5							
AVG	659.3	42.7	882.2	26.5	915.9	556.4	26.48	29.07	34.61	20.17	14.44	50.03	-0.1082

	QE	QO	QV	E(CM)	E(IN)	E(AC-FT)	FINAL STAGE
TOTAL	3779.5	722.6	-243.8	6.5244	2.5686	509.16	1195.42
AVG	466.4	89.2	-30.1	0.8051	0.3169	62.83	

ENERGY BUDGET TSP 4 10.50 07/06/66 TO 8.00 07/12/66

DATE	QS	QR	QA	QAR	QBS	QN	TO	TA	EO	EA	DE	RH	R
			GM*CAL/CM**2				CENTIGRADE			MILLIBARS			
07/06	493.7	37.5	530.6	15.9	519.5	451.4	27.10	33.10	35.85	20.76	15.08	41.04	-0.2346
07/07	661.8	42.6	878.3	26.3	928.1	543.0	27.48	29.75	36.65	24.66	11.99	58.97	-0.1116
07/08	586.9	37.0	920.0	27.6	930.1	512.2	27.64	28.77	37.00	25.59	11.41	64.77	-0.0584
07/09	668.0	42.8	927.0	27.8	927.1	597.3	27.40	30.51	36.49	23.87	12.63	54.63	-0.1453
07/10	672.4	42.9	912.2	27.4	926.8	587.5	27.38	30.46	36.45	21.51	14.94	49.40	-0.1217
07/11	665.2	42.7	889.0	26.7	925.0	559.8	27.24	31.41	36.15	19.11	17.04	41.55	-0.1446
07/12	51.6	6.2	263.5	7.9	307.5	-6.5	27.04	26.82	35.73	20.47	15.27	58.03	0.0085
TOTAL	3799.6	251.9	5320.6	159.6	5464.0	3244.7							
AVG	644.5	42.7	902.4	27.1	926.8	550.3	27.37	30.27	36.44	22.60	13.84	52.87	-0.1205

	QE	QO	QV	E(CM)	E(IN)	E(AC-FT)	FINAL STAGE
TOTAL	2564.8	425.1	-203.5	4.4301	1.7441	341.33	1194.78
AVG	435.0	72.1	-34.5	0.7514	0.2958	57.89	

ENERGY BUDGET TSP 5 8.00 07/12/66 TO 10.00 07/25/66

DATE	QS	QR	QA	QAR	QBS	QN	TO	TA	EO	EA	DE	RH	R
			GM*CAL/CM**2				CENTIGRADE			MILLIBARS			
07/12	636.4	42.0	621.0	18.6	616.9	580.0	27.25	33.12	36.18	17.94	18.24	35.42	-0.1898
07/13	687.4	43.3	874.7	26.2	924.4	568.2	27.18	30.66	36.03	17.94	18.10	40.70	-0.1134
07/14	661.0	42.6	903.5	27.1	929.0	565.7	27.55	31.93	36.82	21.41	15.41	45.20	-0.1676
07/15	540.8	35.6	941.1	28.2	942.1	476.0	28.58	30.66	39.10	23.28	15.82	52.83	-0.0776
07/16	575.0	36.7	938.3	28.1	943.1	505.4	28.68	29.33	39.31	24.42	14.90	59.82	-0.0258
07/17	603.6	37.5	925.9	27.8	948.5	515.7	29.11	30.31	40.31	23.49	16.81	54.38	-0.0423
07/18	643.3	42.1	939.0	28.2	950.5	561.6	29.28	32.00	40.71	24.07	16.64	50.63	-0.0963
07/19	647.9	42.3	948.7	28.5	955.3	570.6	29.66	32.83	41.60	22.09	19.51	44.32	-0.0957
07/20	463.5	32.8	883.4	26.5	945.5	342.0	28.90	27.93	39.83	25.92	13.91	68.86	0.0413
07/21	205.4	19.4	867.8	26.0	932.7	95.1	27.87	24.99	37.50	26.18	11.32	82.74	0.1503
07/22	376.2	29.2	903.0	27.1	927.2	295.8	27.42	26.68	36.53	26.05	10.49	74.46	0.0417
07/23	375.6	29.1	871.6	26.1	925.4	266.6	27.27	24.89	36.22	26.49	9.73	84.17	-0.0000
07/24	296.4	25.1	911.6	27.3	921.9	233.6	26.98	24.70	35.61	25.66	9.95	82.46	0.1354
07/25	135.8	14.0	351.0	10.5	383.3	78.9	26.85	23.91	35.34	25.14	10.20	84.72	0.1704
TOTAL	6848.3	471.6	11880.8	356.4	12245.9	5655.2							
AVG	523.4	36.0	908.1	27.2	936.0	432.2	28.12	28.97	38.10	23.65	14.44	61.11	-0.0234

	QE	QO	QV	E(CM)	E(IN)	E(AC-FT)	FINAL STAGE
TOTAL	5537.7	4447.8	4462.0	9.5656	3.7660	769.82	1196.98
AVG	423.3	340.0	341.0	0.7311	0.2878	58.84	

TABLE XVIII (Continued)

ENERGY BUDGET TSP 6 10.00 07/25/66 TO 12.50 08/02/66

DATE	QS	QR	QA	QAR	QBS	QN	TO	TA	EO	EA	DE	RH	R
			GM*CAL/CM**2				CENTIGRADE			MILLIBARS			
07/25	407.7	34.1	574.4	17.2	541.3	389.5	27.46	28.69	36.63	25.85	10.78	65.73	-0.0670
07/26	655.0	42.5	925.2	27.8	928.6	581.5	27.52	29.24	36.76	24.11	12.65	59.37	-0.0799
07/27	579.1	36.8	857.0	25.7	931.7	441.8	27.77	29.81	37.29	21.43	15.86	51.07	-0.0755
07/28	427.6	31.4	943.4	28.3	936.7	374.6	28.18	30.40	38.19	22.53	15.66	51.91	-0.0834
07/29	501.8	34.2	987.0	29.6	936.2	488.8	28.16	30.68	38.14	23.93	14.21	54.26	-0.1044
07/30	581.5	36.9	870.0	26.1	935.5	453.1	28.09	28.75	37.98	27.91	10.07	70.70	-0.0389
07/31	603.5	37.5	949.7	28.5	943.8	543.4	28.72	29.16	39.41	27.67	11.74	68.45	-0.0221
08/01	619.0	38.0	924.6	27.7	941.1	536.8	28.54	31.49	38.99	26.03	12.96	56.34	-0.1344
08/02	195.2	18.6	426.6	12.8	491.6	98.7	28.76	26.14	39.51	26.66	12.84	78.66	0.1203
TOTAL	4570.5	310.0	7457.7	223.7	7586.3	3908.2							
AVG	564.0	38.3	920.2	27.6	936.1	482.2	28.13	29.60	38.09	25.00	13.10	60.64	-0.0636

	QE	QO	QV	E(CM)	E(IN)	E(AC-FT)	FINAL STAGE
TOTAL	3257.8	438.8	-80.9	5.6375	2.2195	472.80	1199.16
AVG	402.0	54.1	-10.0	0.6956	0.2739	58.34	

ENERGY BUDGET TSP 7 9.50 08/03/66 TO 11.50 08/10/66

DATE	QS	QR	QA	QAR	QBS	QN	TO	TA	EO	EA	DE	RH	R
			GM*CAL/CM**2				CENTIGRADE			MILLIBARS			
08/03	539.0	39.0	489.2	14.7	569.8	404.8	28.68	27.41	39.32	18.32	21.00	50.16	0.0357
08/04	641.1	42.1	820.2	24.6	947.6	447.0	29.02	25.35	40.10	17.60	22.50	54.42	0.0962
08/05	438.4	31.8	862.9	25.9	942.9	300.7	28.66	24.99	39.27	18.48	20.79	58.37	0.1041
08/06	632.0	41.8	850.4	25.5	939.2	475.9	28.36	26.90	38.60	18.24	20.36	51.47	0.0423
08/07	620.2	41.5	860.1	25.8	935.6	477.5	28.09	27.41	37.99	20.70	17.29	56.70	0.0231
08/08	493.4	33.9	828.6	24.9	934.6	328.6	28.01	26.45	37.82	20.78	17.04	60.21	0.0540
08/09	609.3	41.2	893.3	26.8	933.1	501.5	27.88	29.01	37.53	19.93	17.60	49.72	-0.0379
08/10	188.8	18.2	381.3	11.4	443.3	97.1	27.29	22.42	36.26	21.43	14.83	79.03	0.1930
TOTAL	4162.2	289.6	5986.0	179.6	6646.0	3033.0							
AVG	587.6	40.9	845.1	25.4	938.3	428.2	28.29	26.46	38.46	19.35	19.11	56.34	0.0559

	QE	QO	QV	E(CM)	E(IN)	E(AC-FT)	FINAL STAGE
TOTAL	3253.6	-603.7	-203.5	5.6227	2.2137	467.41	1198.69
AVG	459.3	-85.2	-28.7	0.7938	0.3125	65.99	

ENERGY BUDGET TSP 8 9.50 08/12/66 TO 14.00 08/19/66

DATE	QS	QR	QA	QAR	QBS	QN	TO	TA	EO	EA	DE	RH	R
			GM*CAL/CM**2				CENTIGRADE			MILLIBARS			
08/12	437.8	35.4	546.7	16.4	562.6	370.2	27.73	27.29	37.20	22.12	15.08	60.99	0.0170
08/13	289.8	24.7	862.4	25.9	928.1	173.5	27.48	23.98	36.67	24.60	12.07	82.58	0.1714
08/14	447.7	32.2	891.6	26.7	926.1	354.3	27.31	26.29	36.31	24.56	11.75	71.84	0.0515
08/15	605.3	41.1	875.3	26.3	925.4	487.9	27.27	28.89	36.21	25.32	10.90	63.63	-0.0875
08/16	590.2	37.1	882.4	26.5	929.6	479.4	27.60	30.44	36.93	23.75	13.19	54.59	-0.1266
08/17	616.0	41.4	865.2	26.0	932.5	481.4	27.84	30.27	37.44	22.34	15.10	51.86	-0.0948
08/18	544.7	35.7	853.3	25.6	929.8	407.0	27.62	26.80	36.97	23.27	13.70	66.05	0.0354
08/19	342.9	31.0	511.8	15.4	539.7	268.5	27.28	23.05	36.24	22.85	13.39	81.09	0.1865
TOTAL	3874.4	278.6	6288.8	188.7	6673.9	3022.1							
AVG	539.0	38.8	875.0	26.3	928.5	420.5	27.52	27.35	36.75	23.73	13.03	66.05	0.0095

	QE	QO	QV	E(CM)	E(IN)	E(AC-FT)	FINAL STAGE
TOTAL	2776.8	22.6	-88.2	4.7976	1.8888	396.91	1198.43
AVG	386.3	3.1	-12.3	0.6675	0.2628	55.22	

ENERGY BUDGET TSP 9 14.00 08/19/66 TO 8.00 08/28/66

DATE	QS	QR	QA	QAR	QBS	QN	TO	TA	EO	EA	DE	RH	R
			GM*CAL/CM**2				CENTIGRADE			MILLIBARS			
8/19/	168.0	16.6	380.4	11.4	386.0	134.3	27.35	26.15	36.39	23.35	13.04	68.86	0.0544
8/20/	570.9	36.5	902.8	27.1	924.2	485.8	27.17	27.29	36.00	24.90	11.10	68.70	-0.0062
8/21/	264.5	23.2	859.9	25.8	920.7	154.7	26.89	24.45	35.41	25.15	10.26	82.07	0.1403
8/22/	268.5	23.5	802.0	24.1	917.3	105.7	26.61	21.03	34.83	18.25	16.58	73.27	0.2002
8/23/	163.8	16.3	758.1	22.7	909.3	-26.3	25.96	16.44	33.52	15.60	17.92	83.47	0.3173
8/24/	444.9	32.1	773.6	23.2	908.2	255.1	25.84	18.08	33.30	15.56	17.74	75.01	0.2609
8/25/	618.4	38.0	765.1	23.0	906.2	416.4	25.68	19.93	32.99	16.10	16.88	69.19	0.2027
8/26/	588.4	37.1	707.9	21.2	899.6	338.5	25.15	21.22	31.96	16.25	15.71	64.50	0.1487
8/27/	410.5	30.7	809.2	24.3	895.8	268.9	24.84	22.19	31.37	18.54	12.83	69.34	0.1222
8/28/	9.8	1.7	252.4	7.6	296.6	-43.7	24.36	19.69	30.48	20.44	10.04	89.16	0.2751
TOTAL	3507.8	255.7	7011.5	210.3	7963.9	2089.4							
AVG	400.9	29.2	801.3	24.0	910.2	238.8	26.02	21.50	33.68	19.07	14.61	73.60	0.1715

	QE	QO	QV	E(CM)	E(IN)	E(AC-FT)	FINAL STAGE
TOTAL	3553.6	-2119.3	106.3	6.1202	2.4095	506.24	1198.42
AVG	406.1	-242.2	12.1	0.6995	0.2754	57.86	

ENERGY BUDGET TSP 10 8.00 08/28/66 TO 17.00 09/03/66

DATE	QS	QR	QA	QAR	QBS	QN	TO	TA	EO	EA	DE	RH	R
			GM*CAL/CM**2				CENTIGRADE			MILLIBARS			
08/28	373.7	29.0	631.9	19.0	596.9	360.7	24.78	24.73	31.26	22.61	8.65	72.54	0.0035
8/29	439.2	31.9	855.8	25.7	896.9	340.5	24.92	23.90	31.52	22.62	8.90	76.28	0.0677
8/30	442.7	32.0	893.5	26.8	900.3	377.0	25.21	23.86	32.07	23.31	8.76	78.79	0.0911
8/31	424.1	31.3	853.6	25.6	899.7	321.2	25.16	24.22	31.98	23.87	8.11	79.00	0.0690
09/01	382.3	29.4	832.5	25.0	899.1	261.3	25.12	23.61	31.90	23.35	8.55	80.11	0.1040
09/02	540.1	35.5	882.4	26.5	901.3	459.2	25.29	26.15	32.22	24.49	7.73	72.21	-0.0658
09/03	436.2	35.3	654.0	19.6	640.5	394.8	25.55	25.32	32.72	23.88	8.84	73.95	0.0149
TOTAL	3038.3	224.5	5603.6	168.1	5734.6	2514.8							
AVG	476.6	35.2	879.0	26.4	899.5	394.5	25.15	24.50	31.96	23.47	8.48	76.41	0.0438

	QE	QO	QV	E(CM)	E(IN)	E(AC-FT)	FINAL STAGE
TOTAL	1793.0	600.5	-29.8	3.0907	1.2168	255.23	1198.33
AVG	281.2	94.2	-4.7	0.4848	0.1909	40.04	

TABLE XVIII (Continued)

ENERGY BUDGET TSP 11 17.50 09/04/66 TO 17.00 09/12/66

DATE	QS	QR	QA	QAR	QBS	QN	TO	TA	EO	EA	DE	RH	R
			GM*CAL/CM**2				CENTIGRADE			MILLIBARS			
09/04	0.8	0.7	212.3	6.4	246.9	-40.9	26.17	24.21	33.94	22.35	11.59	74.00	0.0999
09/05	566.3	39.9	814.0	24.4	924.3	391.6	27.13	24.38	35.93	20.85	15.08	68.33	0.1081
09/06	547.9	39.3	745.7	22.4	911.3	320.7	26.12	22.79	33.85	18.27	15.58	65.87	0.1266
09/07	555.3	39.6	725.9	21.8	907.7	312.2	25.82	21.28	33.26	16.99	16.27	67.19	0.1663
09/08	313.7	26.0	829.7	24.9	904.9	187.5	25.59	21.61	32.80	19.51	13.29	75.60	0.1783
09/09	334.4	27.1	815.4	24.5	903.6	194.6	25.47	21.69	32.57	19.17	13.40	73.92	0.1676
09/10	387.2	29.7	821.9	24.7	900.5	254.3	25.21	20.51	32.08	18.58	13.50	77.02	0.2069
09/11	198.7	18.9	795.3	23.9	895.9	55.4	24.84	18.66	31.37	17.69	13.67	82.28	0.2673
09/12	296.5	25.1	582.4	17.5	633.1	203.3	24.68	19.27	31.08	18.08	12.99	80.98	0.2467
TOTAL	3200.9	246.2	6342.6	190.3	7228.2	1878.8							
AVG	401.2	30.9	794.9	23.8	905.9	235.5	25.66	21.45	32.97	18.79	14.18	73.64	0.1783

	QE	QO	QV	E(CM)	E(IN)	E(AC-FT)	FINAL STAGE
TOTAL	2339.6	-695.5	-84.8	4.0302	1.5867	331.62	1198.14
AVG	293.2	-87.2	-10.6	0.5051	0.1989	41.56	

ENERGY BUDGET TSP 12 17.00 09/12/66 TO 16.00 09/21/66

DATE	QS	QR	QA	QAR	QBS	QN	TO	TA	EO	EA	DE	RH	R
			GM*CAL/CM**2				CENTIGRADE			MILLIBARS			
9/12/	15.9	2.4	212.9	6.4	261.1	-41.0	24.76	19.15	31.22	17.44	13.78	78.65	0.2407
9/13/	492.1	33.9	809.8	24.3	892.4	351.4	24.55	22.76	30.84	20.89	9.95	75.45	0.1061
9/14/	461.4	32.7	773.4	23.2	892.1	286.7	24.53	22.21	30.79	20.42	10.37	76.27	0.1316
9/15/	88.7	9.9	762.6	22.9	884.6	-66.1	23.91	16.82	29.67	16.03	13.64	83.70	0.3069
9/16/	102.9	11.2	705.9	21.2	879.2	-102.8	23.45	16.18	28.86	17.27	11.59	93.95	0.3706
9/17/	136.4	14.1	811.5	24.3	874.6	34.8	23.06	17.80	28.19	17.90	10.29	87.86	0.3026
9/18/	430.1	31.5	733.2	22.0	872.3	237.4	22.86	18.39	27.85	16.76	11.09	79.27	0.2386
9/19/	355.4	28.2	710.7	21.3	869.7	146.9	22.64	17.41	27.48	14.99	12.49	75.45	0.2483
9/20/	489.3	33.8	685.9	20.6	868.7	252.2	22.55	18.40	27.33	14.15	13.19	66.87	0.1866
9/21/	470.8	33.1	497.1	14.9	583.1	336.8	23.09	17.90	28.24	13.28	14.97	64.78	0.2058
TOTAL	3043.0	230.7	6703.0	201.1	7877.7	1436.5							
AVG	339.7	25.8	748.2	22.4	879.4	160.4	23.46	18.70	28.91	17.01	11.90	78.69	0.2343

	QE	QO	QV	E(CM)	E(IN)	E(AC-FT)	FINAL STAGE
TOTAL	2568.3	-1436.8	398.8	4.4151	1.7382	367.28	1198.72
AVG	286.7	-160.4	44.5	0.4928	0.1940	41.00	

ENERGY BUDGET TSP 13 16.00 09/21/66 TO 15.30 09/29/66

DATE	QS	QR	QA	QAR	QBS	QN	TO	TA	EO	EA	DE	RH	R
			GM*CAL/CM**2				CENTIGRADE			MILLIBARS			
09/21	34.2	4.4	240.1	7.2	297.1	-34.4	24.32	21.18	30.40	12.02	18.38	47.82	0.1010
09/22	511.3	38.1	711.2	21.3	868.0	295.0	22.53	20.51	27.29	13.64	13.65	56.55	0.0874
09/23	488.8	37.3	748.7	22.5	879.8	297.9	23.45	20.37	28.86	12.23	16.63	51.12	0.1097
09/24	503.0	37.8	757.3	22.7	864.7	335.1	22.22	22.13	26.79	12.61	14.18	47.33	0.0039
09/25	465.9	32.9	809.3	24.3	867.8	350.2	22.47	24.23	27.21	16.69	10.51	55.21	-0.0977
09/26	383.8	29.5	833.7	25.0	875.0	288.0	23.09	21.41	28.24	18.75	9.49	73.53	0.1039
09/27	80.3	9.1	756.2	22.7	865.7	-61.1	22.31	16.50	26.94	16.54	10.40	88.15	0.3295
09/28	472.5	36.7	724.9	21.7	867.7	271.3	22.45	17.64	27.16	14.37	12.79	71.26	0.2215
09/29	415.9	34.5	485.3	14.6	553.7	298.5	22.57	21.01	27.37	14.98	12.39	60.20	0.0739
TOTAL	3355.6	260.3	6066.7	182.0	6939.5	2040.5							
AVG	420.5	32.6	760.3	22.8	869.7	255.7	22.69	20.46	27.58	14.84	12.74	62.35	0.1051

	QE	QO	QV	E(CM)	E(IN)	E(AC-FT)	FINAL STAGE
TOTAL	2537.4	-701.1	-72.5	4.3590	1.7162	361.29	1198.53
AVG	318.0	-87.9	-9.1	0.5463	0.2151	45.28	

ENERGY BUDGET TSP 14 15.50 09/29/66 TO 15.00 10/06/66

DATE	QS	QR	QA	QAR	QBS	QN	TO	TA	EO	EA	DE	RH	R
			GM*CAL/CM**2				CENTIGRADE			MILLIBARS			
9/29/	51.9	6.3	277.1	8.3	307.1	7.3	22.36	25.12	27.02	17.63	9.39	55.27	-0.1718
9/30/	119.2	12.6	695.2	20.9	853.2	-72.3	21.23	15.41	25.22	12.23	12.99	69.89	0.2641
0/01/	495.4	34.0	653.2	19.6	851.1	243.9	21.03	13.66	24.91	8.50	16.40	54.41	0.2664
0/02/	464.0	32.8	696.1	20.9	836.9	269.5	19.82	16.58	23.11	10.34	12.78	54.81	0.1490
0/03/	436.0	31.7	767.8	23.0	834.1	314.9	19.57	21.75	22.76	14.71	8.05	56.50	-0.1584
0/04/	178.8	17.4	707.9	21.2	827.8	20.2	19.02	14.93	22.00	9.80	12.19	57.79	0.1992
0/05/	298.3	25.2	700.5	21.0	827.7	124.8	19.00	15.38	21.96	9.03	12.93	51.72	0.1668
0/06/	368.2	28.8	439.0	13.2	516.2	249.1	18.86	15.49	21.77	8.62	13.15	49.00	0.1522
TOTAL	2411.7	188.9	4936.9	148.1	5854.1	1157.5							
AVG	345.6	27.1	707.4	21.2	838.8	165.9	19.97	16.66	23.38	10.92	12.45	56.64	0.1320

	QE	QO	QV	E(CM)	E(IN)	E(AC-FT)	FINAL STAGE
TOTAL	3384.9	-2874.5	-88.7	5.7913	2.2801	477.01	1198.20
AVG	485.0	-411.9	-12.7	0.8298	0.3267	68.35	

ENERGY BUDGET TSP 15 15.00 10/06/66 TO 11.50 10/15/66

DATE	QS	QR	QA	QAR	QBS	QN	TO	TA	EO	EA	DE	RH	R
			GM*CAL/CM**2				CENTIGRADE			MILLIBARS			
0/06/	65.4	7.6	260.7	7.8	310.6	0.1	19.03	18.47	22.01	9.64	12.37	45.39	0.0272
0/07/	384.1	29.5	726.2	21.8	823.3	235.7	18.62	18.18	21.45	11.36	10.09	54.43	0.0255
0/08/	329.2	26.8	774.9	23.2	822.1	231.8	18.51	19.76	21.31	13.52	7.79	58.70	-0.0941
0/09/	451.4	32.4	706.3	21.2	826.2	278.0	18.86	21.23	21.77	14.13	7.65	56.03	-0.1822
0/10/	476.3	33.3	597.1	17.9	824.7	197.5	18.73	17.02	21.60	7.20	14.41	37.12	0.0707
0/11/	439.8	31.9	690.1	20.7	824.8	252.5	18.75	19.14	21.63	11.14	10.48	50.31	-0.0217
0/12/	401.6	30.3	764.1	22.9	823.9	288.5	18.68	20.83	21.53	18.21	3.32	74.02	-0.3794
0/13/	422.4	31.2	790.3	23.7	827.1	330.7	18.94	25.37	21.89	20.88	1.01	64.47	-3.7200
0/14/	426.2	31.3	635.4	19.1	829.8	181.4	19.18	19.48	22.21	13.04	9.17	57.61	-0.0197
0/15/	188.5	18.2	246.2	7.4	392.4	16.7	18.25	8.64	20.96	6.99	13.96	62.44	0.4098
TOTAL	3584.9	272.5	6191.1	185.7	7304.8	2012.9							
AVG	404.9	30.8	699.2	21.0	825.0	227.3	18.77	19.43	21.65	13.15	8.50	56.43	-0.4647

	QE	QO	QV	E(CM)	E(IN)	E(AC-FT)	FINAL STAGE
TOTAL	5111.7	-1009.0	-123.2	8.7388	3.4405	715.03	1197.85
AVG	577.3	-114.0	-13.9	0.9870	0.3886	80.76	

APPENDIX C

EVAPORATION REDUCTIONS RESULTING FROM APPLICATION OF MONOMOLECULAR FILMS TO EVAPORATION PANS AND TANKS

TABLE XIX

EVAPORATION REDUCTIONS RESULTING FROM APPLICATION OF MONOMOLECULAR FILMS TO EVAPORATION PANS AND TANKS

Date	Class A Pans			Sunken Class A Pans			Sunken 4-Foot Tanks			Sunken 9-Foot Tanks		
	Evap TR(a)	Evap UT	Red	Evap TR	Evap UT	Red	Evap TR	Evap UT	Red	Evap	Evap	Red
	in/day	in/day	%	in/day	in/day	%	in/day	in/day	%	in/day	in/day	%
06 11 1966 (b)		0.69										
06 12 1966		0.47										
06 14 1966		0.60										
06 15 1966		0.53										
BEGIN NEW TREATMENT PERIOD												
06 17 1966		0.30										
06 18 1966		0.17										
06 19 1966		0.28										
06 20 1966		0.32										
06 21 1966		0.41										
06 22 1966		0.47										
06 23 1966		0.49										
06 24 1966	0.19	0.47	59.6									
06 25 1966	0.19	0.52	63.9									
06 26 1966	0.22	0.41	45.1									
06 27 1966	0.20	0.42	52.0									
06 28 1966	0.25	0.54	53.4									
06 29 1966	0.23	0.53	56.6								0.24	
06 30 1966	0.23	0.50	54.7								0.38	
07 01 1966	0.22	0.38	42.6								0.27	
07 02 1966	0.30	0.69	56.8								0.52	
07 03 1966	0.16	0.29	44.3								0.25	
07 04 1966	0.22	0.42	46.4								0.30	
07 05 1966	0.24	0.52	52.9								0.42	
07 06 1966	0.31	0.72	57.4								0.43	
07 07 1966	0.24	0.36	34.3								0.36	
07 08 1966	0.20	0.50	60.4								0.35	
07 09 1966	0.24	0.49	51.0								0.37	
07 10 1966	0.27	0.59	54.8								0.41	
07 11 1966	0.27	0.64	57.5								0.48	
07 12 1966	0.32	0.70	54.3								0.51	
07 13 1966	0.33	0.65	49.2								0.47	
07 14 1966	0.36	0.62	42.2								0.47	
07 15 1966	0.28	0.55	48.8								0.40	
07 16 1966	0.22	0.39	44.0								0.42	
07 17 1966	0.20	0.39	47.4								0.34	
07 18 1966	0.23	0.46	50.7								0.40	
07 19 1966	0.30	0.61	50.8								0.62	
BEGIN NEW TREATMENT PERIOD												
07 25 1966	0.10	0.18	46.3							0.07	0.10	30.0
07 26 1966	0.15	0.39	62.4							0.18	0.30	40.0
07 27 1966	0.25	0.50	50.0							0.22	0.38	42.1
07 28 1966	0.22	0.49	54.7							0.23	0.43	46.5
07 29 1966	0.16	0.32	49.5							0.14	0.19	26.3
07 30 1966	0.21	0.40	47.9							0.16	0.31	48.4
BEGIN NEW TREATMENT PERIOD												
08 01 1966	0.21	0.40	48.3							0.22	0.32	31.2
08 02 1966	0.23	0.41	44.7							0.25	0.39	35.9
08 03 1966	0.20	0.39	48.7							0.22	0.36	38.9
08 04 1966	0.20	0.33	40.4							0.14	0.28	50.0
08 05 1966	0.15	0.35	56.2							0.14	0.26	46.2
08 06 1966	0.12	0.26	53.2							0.13	0.22	40.9
08 07 1966	0.19	0.40	51.7							0.16	0.31	48.4
08 08 1966	0.20	0.35	43.4							0.15	0.27	44.4
08 09 1966	0.15	0.30	50.5							0.17	0.30	43.3
BEGIN NEW TREATMENT PERIOD												
08 12 1966	0.13	0.18	29.1	0.12	0.19	36.8				0.12	0.22	45.5
08 13 1966	0.12	0.26	53.2	0.14	0.17	17.6				0.10	0.28	64.3
08 14 1966	0.09	0.18	51.8	0.13	0.25	48.0				0.09	0.13	30.8
08 15 1966	0.13	0.30	57.8	0.11	0.26	57.7				0.11	0.26	57.7
08 16 1966	0.23	0.49	52.7	0.19	0.42	54.8	0.12	0.40	70.0	0.18	0.35	48.6
08 17 1966	0.27	0.52	48.5	0.21	0.41	48.8	0.16	0.40	60.0	0.24	0.38	36.8
08 18 1966	0.27	0.54	50.9	0.23	0.41	43.9	0.19	0.41	53.7	0.23	0.43	46.5

(a) Symbol Code: Evap = Evaporation
TR = Evaporation from treated pans or tanks
UT = Evaporation from untreated pans or tanks
RED = Evaporation Reduction

(b) Evaporation was measured at 0900 each day until September 19, 1966. After September 19, evaporation was measured at 1600 on the days listed above.

TABLE XIX (Continued)

Date	Class A Pans			Sunken Class A Pans			Sunken 4-Foot Tanks			Sunken 9-Foot Tanks		
	Evap TR(a)	Evap UT	Red	Evap TR	Evap UT	Red	Evap TR	Evap UT	Red	Evap	Evap	Red
	in/day	in/day	%	in/day	in/day	%	in/day	in/day	%	in/day	in/day	%
BEGIN NEW TREATMENT PERIOD												
08 21 1966	0.18	0.37	50.7	0.17	0.32	46.9	0.14	0.31	54.8	0.23	0.24	4.2
08 22 1966	0.06	0.16	62.5	0.01	0.20	95.0	0.05	0.19	73.7	0.09	0.17	47.1
BEGIN NEW TREATMENT PERIOD												
08 25 1966	0.08	0.11	31.8	0.06	0.04	-50.0	0.07	0.11	36.4	0.03	0.10	70.0
08 26 1966	0.11	0.26	56.9	0.11	0.13	15.4	0.11	0.20	45.0	0.07	0.16	56.2
08 27 1966	0.09	0.32	71.4	0.08	0.19	57.9	0.09	0.25	64.0	0.13	0.29	55.2
08 28 1966	0.09	0.22	61.4	0.09	0.19	52.6	0.07	0.18	61.1	0.10	0.22	54.5
08 29 1966	0.13	0.23	44.4	0.10	0.18	44.4	0.10	0.19	47.4	0.08	0.15	46.7
08 30 1966	0.06	0.21	71.4	0.09	0.18	50.0	0.08	0.14	42.9	0.06	0.12	50.0
BEGIN NEW TREATMENT PERIOD												
09 01 1966	0.10	0.24	58.3	0.09	0.19	52.6	0.09	0.20	55.0	0.13	0.18	27.8
09 02 1966	0.07	0.22	67.4	0.05	0.17	70.6	0.05	0.18	72.2	0.12	0.18	33.3
09 03 1966	0.16	0.31	50.0	0.14	0.27	48.1	0.12	0.23	47.8	0.12	0.23	47.8
BEGIN NEW TREATMENT PERIOD												
09 05 1966	0.11	0.14	25.0	0.06	0.11	45.5	0.09	0.08	-12.5	0.10	0.08	-25.0
09 06 1966	0.15	0.25	42.0	0.14	0.20	30.0	0.15	0.22	31.8	0.13	0.34	61.8
09 07 1966	0.12	0.23	47.8	0.13	0.26	50.0	0.14	0.30	53.3	0.13	0.27	51.8
09 08 1966	0.11	0.24	54.2	0.12	0.19	36.8	0.14	0.19	26.3	0.12	0.22	45.5
09 09 1966	0.07	0.15	56.7	0.09	0.15	40.0	0.11	0.18	38.9	0.11	0.19	42.1
09 10 1966	0.07	0.16	56.2	0.04	0.13	69.2	0.10	0.15	33.3	0.06	0.12	50.0
09 11 1966	0.09	0.19	54.1	0.10	0.17	41.2	0.12	0.17	29.4	0.11	0.18	38.9
09 12 1966	0.05	0.08	43.7	0.06	0.09	33.3	0.06	0.11	45.5	0.05	0.12	58.3
BEGIN NEW TREATMENT PERIOD												
09 15 1966	0.08	0.29	71.9	0.07	0.22	68.2	0.10	0.15	33.3	0.12	0.23	47.8
BEGIN NEW TREATMENT PERIOD												
09 19 1966	0.08	0.26	69.2	0.07	0.18	61.1	0.07	0.22	68.2	0.07	0.20	65.0
09 21 1966	0.11	0.44	74.7	0.12	0.26	53.8	0.10	0.37	73.0	0.12	0.30	60.0
09 23 1966	0.21	0.42	51.2	0.21	0.37	43.2	0.15	0.38	60.5	0.15	0.34	55.9
09 24 1966	0.13	0.35	62.9	0.13	0.29	55.2	0.11	0.25	56.0	0.13	0.23	43.5
09 25 1966	0.11	0.34	69.1	0.10	0.25	60.0	0.11	0.28	60.7	0.12	0.27	55.6
09 26 1966	0.11	0.20	46.2	0.11	0.17	35.3	0.09	0.13	30.8	0.07	0.12	41.7
BEGIN NEW TREATMENT PERIOD												
09 29 1966	0.10	0.30	67.8	0.07	0.33	78.8	0.08	0.27	70.4	0.10	0.23	56.5
10 01 1966	0.19	0.38	49.3	0.14	0.27	48.1	0.20	0.46	56.5	0.27	0.41	34.1
10 02 1966	0.08	0.28	73.2	0.06	0.19	68.4	0.08	0.26	69.2	0.20	0.24	16.7
10 03 1966	0.08	0.29	72.4	0.10	0.20	50.0	0.09	0.23	60.9	0.15	0.23	34.8
10 04 1966	0.10	0.22	55.8	0.10	0.23	56.5	0.10	0.26	61.5	0.11	0.23	52.2
10 06 1966	0.11	0.31	65.6	0.12	0.28	57.1	0.07	0.33	78.8	0.08	0.24	66.7
10 08 1966	0.19	0.47	60.6	0.21	0.41	48.8	0.16	0.40	60.0	0.12	0.41	70.7
10 09 1966	0.07	0.23	71.1	0.13	0.18	27.8	0.06	0.18	66.7	0.11	0.15	26.7
10 11 1966	0.22	0.53	59.0	0.28	0.47	40.4	0.19	0.47	59.6	0.16	0.42	61.9
10 12 1966	0.10	0.23	56.5	0.04	0.13	69.2	0.03	0.14	78.6	0.09	0.14	35.7
10 13 1966	0.08	0.24	66.7	0.08	0.15	46.7	0.04	0.12	66.7	0.09	0.11	18.2
10 15 1966	0.31	0.73	58.2	0.20	0.62	67.7	0.35	0.79	55.7	0.62	0.77	19.5
10 16 1966	0.05	0.14	66.7	0.07	0.16	56.2	0.07	0.16	56.2	0.02	0.13	84.6
BEGIN NEW TREATMENT PERIOD												
10 20 1966	0.06	0.36	83.3	0.07	0.36	80.6	0.09	0.41	78.0	0.19	0.34	44.1
10 22 1966	0.16	0.56	71.2	0.12	0.43	72.1	0.14	0.50	72.0	0.36	0.47	23.4
10 23 1966	0.04	0.14	70.4	0.04	0.13	69.2	0.04	0.15	73.3	0.02	0.12	83.3
10 25 1966	0.08	0.29	71.9	0.11	0.22	50.0	0.08	0.26	69.2	0.06	0.20	70.0
10 27 1966	0.12	0.35	65.7	0.09	0.28	67.9	0.08	0.29	72.4	0.07	0.25	72.0
10 29 1966	0.12	0.44	72.7	0.23	0.40	42.5	0.14	0.42	66.7	0.15	0.36	58.3
11 01 1966	0.22	0.62	65.3	0.20	0.56	64.3	0.25	0.65	60.0	0.38	0.60	36.7
11 03 1966	0.05	0.15	65.5	0.02	0.18	88.9	0.05	0.29	82.8	0.06	0.25	76.0
11 05 1966	0.06	0.22	75.0	0.05	0.19	73.7	0.05	0.20	75.0	0.04	0.12	66.7
11 06 1966	0.02	0.11	81.8	0.01	0.10	90.0	0.02	0.09	77.8	0.04	0.01	*****
11 08 1966	0.17	0.63	73.8	0.09	0.40	77.5	0.09	0.32	71.9	0.16	0.34	52.9
11 11 1966	0.14	0.52	73.8	0.13	0.47	72.3	0.14	0.59	76.3	0.27	0.54	50.0
11 12 1966	0.02	0.09	77.8	0.02	0.09	77.8	0.04	0.12	66.7	0.02	0.09	77.8
11 16 1966	0.17	0.75	77.2	0.16	0.53	69.8	0.13	0.52	75.0	0.25	0.46	45.7
11 19 1966	0.20	0.67	70.7	0.17	0.48	64.6	0.17	0.53	67.9	0.28	0.48	41.7
11 20 1966	0.02	0.12	82.6	0.04	0.10	60.0	0.03	0.10	70.0	0.03	0.07	57.1
11 27 1966	0.42	1.19	64.7	0.24	0.82	70.7	0.40	0.87	54.0	0.66	0.86	23.3
12 04 1966	0.16	0.53	70.5	0.16	0.53	69.8	0.14	0.67	79.1	0.29	0.57	49.1

APPENDIX D

WATER SURFACE TEMPERATURES OF TREATED AND UNTREATED PANS AND TANKS

TABLE XX

WATER SURFACE TEMPERATURES OF TREATED AND UNTREATED PANS AND TANKS

Date	Class A Pans			Sunken Class A Pans			Sunken 4-Foot Tanks			Sunken 9-Foot Tanks			Sunken 15-Foot Tank
	TR (a)	UT	ΔT	TR	UT	ΔT	TR	UT	ΔT	TR	UT	ΔT	UT
	°Centigrade												
06/24/66	29.72												
06/25/66	30.83												
06/26/66	31.28												
06/27/66	30.72												
06/28/66	30.83												
06/29/66	31.78												
06/30/66	32.61												
07/01/66	32.94												
07/02/66	32.89												
07/03/66	33.39												
07/04/66													
07/05/66													
07/06/66	33.83												
07/07/66	33.83												
07/08/66	32.39												
07/09/66	33.33												
07/10/66	33.50												
07/11/66	33.44												
07/12/66	33.50												
07/13/66	33.61												
07/14/66	33.50												
07/15/66	33.39												
07/16/66	33.61	27.78	5.83										
07/17/66	34.22	28.17	6.06										
07/18/66	34.67	29.28	5.39										
07/19/66	35.17	29.83	5.33										
07/20/66	31.89	28.06	3.83										
07/21/66	27.17	24.94	2.22							29.78	26.78	3.00	
07/22/66	28.56	26.33	2.22							28.83	27.06	1.78	26.83
07/23/66	28.11	26.39	1.72							29.17	26.83	2.33	27.11
07/24/66	27.83	26.56	1.28							29.33	26.72	2.61	27.39
07/25/66	30.33	27.89	2.44							30.33	27.61	2.72	27.89
07/26/66	31.94	28.50	3.44							30.78	28.06	2.72	28.06
07/27/66	32.00	27.56	4.44							31.56	28.00	3.56	28.00
07/28/66	32.33	27.94	4.39							31.50	27.28	4.22	27.72
07/29/66	33.17	28.39	4.78							32.06	27.83	4.22	28.00
07/30/66	33.11	28.94	4.17							33.28	29.17	4.11	29.28
07/31/66		29.89								33.61	30.44	3.17	30.17
08/01/66	33.72	29.22	4.50							33.00	29.11	3.89	29.11
08/02/66	31.39	26.72	4.67							31.17	28.06	3.11	28.06
08/03/66	30.72									30.72	26.67	4.06	26.83
08/04/66	30.72												
08/05/66	29.11	25.11	4.00							31.00	27.17	3.83	27.17
08/06/66	31.17	26.56	4.61							31.50	27.28	4.22	27.33
08/07/66	32.33	28.33	4.00							32.33	27.83	4.50	27.83
08/08/66	31.22	27.22	4.00							31.89	27.89	4.00	27.94
08/09/66	31.89	27.06	4.83							32.17			27.83
08/10/66	29.33	28.11	1.22							30.83	27.11	3.72	27.22
08/11/66	28.89	28.50	0.39							30.72	27.11	3.61	27.22
08/12/66	30.06	28.00	2.06							30.94	27.11	3.83	27.22
08/13/66	27.56	25.22	2.33							29.67	26.11	3.56	26.72
08/14/66	29.44	26.61	2.83							30.11	26.67	3.44	27.06
08/15/66	31.67	27.61	4.06							31.17	27.28	3.89	27.06
08/16/66	32.83	28.06	4.78							31.72	27.72	4.00	27.50
08/17/66	32.72	28.00	4.72							32.11	28.00	4.11	27.83
08/18/66	30.78									31.00	27.83	3.17	27.83
08/19/66	27.44	25.11	2.33							29.72	27.72	2.00	27.56
08/20/66	30.61	27.11	3.50							29.89	28.50	1.39	27.39
08/21/66	27.67	25.22	2.44							28.83	27.44	1.39	26.78
08/22/66	24.89	22.06	2.83							27.00	24.94	2.06	25.17
08/23/66	19.61	17.39	2.22	22.33	20.61	1.72	24.06	22.00	2.06	24.00	20.72	3.28	22.44
08/24/66	22.33	20.61	1.72	24.44	23.67	0.78	24.17	22.94	1.22	24.50	21.11	3.39	22.28
08/25/66	26.17	22.89	3.28	26.67	26.11	0.56	25.28	23.83	1.44	26.28	23.22	3.06	23.11
08/26/66	26.72	22.39	4.33	26.67	25.06	1.61	24.28	23.89	0.39	27.00	23.78	3.22	23.44
08/27/66	25.72	22.50	3.22	26.56	24.11	2.44		23.94		26.83	23.39	3.44	23.56
08/28/66	26.50	23.78	2.72	27.06	24.78	2.28		24.72		26.89	23.94	2.94	23.83
08/29/66	28.06	24.78	3.28	28.28	25.72	2.56	27.39	25.67	1.72	27.83	25.11	2.72	24.61
08/30/66	28.22	24.89	3.33	28.56	26.17	2.39	27.61	26.17	1.44	28.50	25.72	2.78	25.33
08/31/66	27.56	24.72	2.83	28.11	26.17	1.94	27.67	26.67	1.00	28.17	25.61	2.56	25.39

(a) Symbol Code: TR = Temperature of treated pan or tank.
UT = Temperature of untreated pan or tank.
ΔT = Difference between temperatures of treated and untreated pan or tank.

TABLE XX (Continued)

Date	Class A Pans			Sunken Class A Pans			Sunken 4-Foot Tanks			Sunken 9-Foot Tanks			Sunken 15-Foot Tank
	TR (a)	UT	ΔT	TR	UT	ΔT	TR	UT	ΔT	TR	UT	ΔT	UT
	°Centigrade												
09/01/66	27.00	24.28	2.72	27.67	25.44	2.22	27.22	26.33	0.89	27.44	25.33	2.11	25.28
09/02/66	29.67	26.33	3.33	29.94	26.94	3.00	29.00	27.39	1.61	28.33	26.28	2.06	25.89
09/03/66	29.67	26.28	3.39	30.11	27.44	2.67	29.39	27.78	1.61	29.67	27.22	2.44	26.61
09/04/66	28.94	27.39	1.56	29.83	28.50	1.33	29.17	29.83	-0.67	30.00	28.44	1.56	26.83
09/05/66	30.56	28.44	2.11	30.44	29.06	1.39	29.61	29.89	-0.28	30.39	29.06	1.33	27.28
09/06/66	28.56	24.44	4.11	29.06	26.39	2.67	28.44	27.28	1.17	29.06	26.56	2.50	26.61
09/07/66	26.94			27.56	25.00	2.56	27.67	25.61	2.06	28.39	24.78	3.61	26.00
09/08/66	25.61	23.06	2.56	26.61	24.72	1.89	26.94	25.17	1.78	27.78	23.06	4.72	25.28
09/09/66	24.94	22.89	2.06	25.89	24.22	1.67	26.06	24.78	1.28	26.83	22.89	3.94	24.56
09/10/66	25.61	22.72	2.89	25.83	24.28	1.56	25.78	25.22	0.56	26.78	22.72	4.06	24.50
09/11/66	21.83	19.83	2.00							25.11	19.83	5.28	23.44
09/12/66	22.44	21.00	1.44		22.50		24.44	23.72	0.72	25.00	21.06	3.94	23.00
09/13/66	25.78	23.11	2.67	25.00	23.17	1.83	25.00	24.72	0.28	26.06	23.00	3.06	23.22
09/14/66	26.61	23.67	2.94	25.22	24.67	0.56	25.06	25.56	-0.50	26.17	23.67	2.50	23.28
09/15/66	19.89	17.56	2.33	21.56	21.00	0.56	23.17	22.61	0.56		17.56		21.83
09/16/66	18.56			20.56	19.83	0.72	21.61	21.89	-0.28		17.56		20.61
09/17/66	19.50	18.61	0.89	21.00	20.11	0.89	21.11	22.06	-0.94	21.61	19.78	1.83	20.44
09/18/66	22.33	20.44	1.89	23.11	21.50	1.61	22.17	22.50	-0.33	23.00	21.00	2.00	20.94
09/19/66	21.11	18.61	2.50	22.11	20.28	1.83	22.17	20.72	1.44	22.56	20.11	2.44	20.39
09/20/66	22.78	19.94	2.83	23.22	21.61	1.61	23.11	20.61	2.50	23.33	20.39	2.94	20.44
09/21/66	25.06	21.89	3.17	24.22	23.06	1.17	24.28	21.94	2.33	24.67	21.94	2.72	21.56
09/22/66	25.67	21.78	3.89	25.00	23.17	1.83	24.94	22.17	2.78	25.11	22.11	3.00	21.50
09/23/66	25.72	21.94	3.78	24.78	23.17	1.61	25.28	22.72	2.56	25.50	22.72	2.78	22.22
09/24/66	25.78	20.83	4.94	25.11	22.06	3.06	25.39	22.28	3.11	25.39	22.00	3.39	21.72
09/25/66	27.28	23.11	4.17	26.67	23.44	3.22	26.33	23.17	3.17	26.28	22.50	3.78	22.28
09/26/66	26.72	23.44	3.28	26.33	24.22	2.11	26.17	23.94	2.22	26.50	23.22	3.28	22.89
09/27/66	19.56	17.50	2.06	21.11	19.94	1.17	22.78	21.33	1.44	22.67	20.11	2.56	21.00
09/28/66	22.11	19.94	2.17	22.50	22.00	0.50	22.50	22.83	-0.33	22.78	20.17	2.61	20.50
09/29/66	25.67	22.06	3.61	24.72	23.78	0.94	24.06	23.61	0.44	24.67	21.72	2.94	21.44
09/30/66	18.44	15.33	3.11	20.06	18.44	1.61	20.89	19.33	1.56	19.94	17.83	2.11	19.00
10/01/66	18.50	15.28	3.22	19.39	18.39	1.00	19.89	17.72	2.17	19.00	16.28	2.72	17.50
10/02/66	20.28	15.11	5.17	20.67	18.06	2.61	20.72	17.39	3.33	18.28	16.06	2.22	16.67
10/03/66	24.22	20.56	3.67	23.89	21.17	2.72	23.00	20.06	2.94	21.11	18.44	2.67	18.17
10/04/66	19.44	15.78	3.67	20.39	16.89	3.50	20.72	17.11	3.61	19.61	16.94	2.67	17.28
10/05/66	18.72	15.50	3.22	19.50	17.17	2.33	19.83	16.72	3.11	19.33	16.22	3.11	16.39
10/06/66	21.00	17.00	4.00	20.33	18.00	2.33	20.78	17.56	3.22	20.50	16.94	3.56	17.00
10/07/66	21.67	16.83	4.83	20.94	18.50	2.44	21.39	18.11	3.28	20.44	16.33	4.11	17.28
10/08/66	22.83	16.17	6.67	21.39	19.17	2.22	22.06	18.89	3.17	21.17	16.89	4.28	16.89
10/09/66	24.89	21.11	3.78	23.39	21.22	2.17	23.50	20.61	2.89	23.33	20.00	3.33	19.67
10/10/66	22.56	17.44	5.11	21.67	18.61	3.06	22.44	19.11	3.33	22.33	18.33	4.00	18.39
10/11/66	22.50	18.11	4.39	21.33	18.94	2.39	22.67	19.22	3.44	22.56	18.50	4.06	18.78
10/12/66	24.11	21.17	2.94	23.67	21.61	2.06	23.94	20.78	3.17	22.61	20.00	2.61	19.50
10/13/66	27.22	24.06	3.17	26.39	24.33	2.06	25.89	22.83	3.06	24.44	22.44	2.00	21.44
10/14/66	22.89	18.72	4.17	24.78	20.56	4.22	24.44	21.00	3.44	22.50	20.39	2.11	20.56
10/15/66	14.11	11.44	2.67					13.56		15.33	13.06	2.28	15.22
10/16/66	16.28	12.39	3.89	16.44	12.56	3.89	18.33	14.67	3.67	16.56	13.22	3.33	14.78
10/17/66	12.39	10.06	2.33	14.17	11.72	2.44	16.67	13.94	2.72	15.78	12.72	3.06	14.17
10/18/66	12.17	10.94	1.22	14.28	12.17	2.11	15.50	13.56	1.94	14.83	12.61	2.22	13.89
10/19/66	13.22	11.17	2.06	13.78	11.06	2.72	14.67	12.11	2.56	13.11	11.22	1.89	12.72
10/20/66	15.61	11.33	4.28	14.94	10.83	4.11	15.67	12.28	3.39	13.83	11.33	2.50	12.22
10/21/66	17.67	13.61	4.06	16.61	13.00	3.61	16.78	13.22	3.56	14.11	12.00	2.11	12.28
10/22/66	17.22	13.22	4.00	16.39	12.50	3.89	16.72	13.28	3.44	14.89	12.72	2.17	12.72
10/23/66	14.56	10.89	3.67	14.33			15.94	12.61	3.33	14.89	11.89	3.00	12.44
10/24/66	16.11	12.61	3.50	15.17	13.33	1.83	16.44	13.50	2.94	15.83	12.89	2.94	13.00
10/25/66	18.78	15.39	3.39	16.61	15.22	1.39	18.00	14.44	3.56	17.22	14.39	2.83	14.17
10/26/66	21.06	17.44	3.61	18.33	16.78	1.56	18.72	16.11	2.61	18.83	15.94	2.89	15.33
10/27/66	20.94	15.83	5.11	18.67	15.67	3.00	19.28	15.56	3.72	19.00	15.39	3.61	15.00
10/28/66	21.28	16.67	4.61	18.28	15.94	2.33	19.56	15.89	3.67	19.39	15.17	4.22	15.50
10/29/66	18.39	15.56	2.83	16.56	15.50	1.06	18.33	15.56	2.78	18.44	15.17	3.28	15.28
10/30/66	18.22	15.11	3.11	16.28	15.17	1.11	18.17	15.56	2.61	18.39	15.28	3.11	15.39
10/31/66	17.22	13.39	3.83	15.83	13.22	2.61	17.33	14.33	3.00	16.83	13.22	3.61	14.39
11/01/66	9.44	6.56	2.89	11.17	8.28	2.89	13.94	10.89	3.06	12.06	8.72	3.33	11.56
11/02/66	4.67	3.33	1.33	7.39	6.50	0.89	10.67	7.89	2.78	9.33	5.94	3.39	8.78
11/03/66	8.61	6.72	1.89	9.89	7.94	1.94	11.33	8.72	2.61	10.39	7.17	3.22	8.72
11/04/66	12.17	9.67	2.50	11.67	9.67	2.00	12.50	10.28	2.22	12.00	9.22	2.78	10.06
11/05/66	12.22	9.94	2.28	12.22	10.33	1.89	12.78	10.56	2.22	12.06	9.33	2.72	10.00
11/06/66	17.22	14.50	2.72	15.72	13.17	2.56	15.89	13.61	2.28	14.33	12.11	2.22	11.50
11/07/66	21.00	17.28	3.72	18.44	15.72	2.72	17.94	15.22	2.72	16.67	15.11	1.56	13.94
11/08/66	23.28	18.61	4.67	20.11	16.83	3.28	20.11	17.17	2.94	18.72	16.67	2.06	15.72
11/09/66	12.11			14.00				13.44		14.67	12.61	2.06	13.89
11/10/66	9.06	6.22	2.83	10.83	7.94	2.89	13.44	10.39	3.06	12.06	8.78	3.28	11.28
11/11/66	12.56	9.28	3.28	11.50	8.72	2.78	13.56	10.72	2.83	12.22	9.11	3.11	10.72
11/12/66	10.94	8.33	2.61	10.44	7.72	2.72	12.89	10.28	2.61	11.78	8.94	2.83	10.33
11/13/66	14.83	11.89	2.94	12.39	10.28	2.11	13.83	11.39	2.44	13.06	10.61	2.44	11.28
11/14/66	16.33						14.72	12.50	2.22		12.50		12.50
11/15/66	16.83						15.44	12.44	3.00		12.44		12.44
11/16/66	18.61			13.67			16.72	13.33	3.39		13.33		13.33
11/17/66	19.72	14.50	5.22	14.28	10.67	3.61	17.67	14.67	3.00	14.94	13.22	1.72	13.00
11/18/66	16.94						17.00	14.39	2.61		14.39		14.39
11/19/66	12.44										13.61		13.61
11/20/66	16.44	14.06	2.39							15.22	12.83	2.39	12.89
11/21/66	19.33	16.50	2.83							16.06	14.67	1.39	14.00
11/22/66	21.17	18.33	2.83							17.50	16.22	1.28	15.33
11/23/66	20.28	17.56	2.72							17.83	16.83	1.00	16.11
11/24/66	18.72	17.00	1.72							17.83	16.56	1.28	16.22
11/25/66	17.61	16.39	1.22							17.67	16.39	1.28	16.28
11/26/66	15.50	14.56	0.94							17.06	15.33	1.72	15.56
11/27/66	9.11	7.33	1.78							10.28	9.67	0.61	11.89
11/28/66	7.00	5.39	1.61							9.17	7.56	1.61	9.56
11/29/66	9.33	6.78	2.56							9.67	7.50	2.17	9.06
11/30/66	7.39	5.50	1.89							8.83	7.00	1.83	8.44
12/01/66	3.06	2.56	0.50							7.39	5.00	2.39	7.06
12/02/66	0.17	0.11	0.06							3.78	1.78	2.00	5.06
12/03/66	0.17	-0.22	0.39							1.67	0.67	1.00	2.83

APPENDIX E

1965 SUMMARY TABLE OF DAILY AND CUMULATIVE EVAPORATION

LAKE, POND, CRI, AND UNTREATED CLASS A PAN

1966 SUMMARY TABLE OF DAILY AND CUMULATIVE EVAPORATION FROM LAKE, POND,

CRI, UNTREATED TANKS, AND UNTREATED CLASS A PAN

TABLE XXI

1965 SUMMARY TABLE OF DAILY AND CUMULATIVE EVAPORATION
LAKE, POND, CRI, AND UNTREATED CLASS A PAN

Date 1965	Lake Hefner Water Budget Daily in/day (a)	Lake Hefner Water Budget Cum inches	Stillwater Pond Daily in/day	Stillwater Pond Cum inches	CRI Daily in/day (b)	CRI Cum inches	Class A Pan Daily in/day (c)
6/03	0.065	0.065			0.27	0.27	---
6/04	0.221	0.286			0.38	0.65	---
6/05	0.280	0.566			0.28	0.93	---
6/06	0.053	0.619			0.26	1.19	---
6/07	0.258	0.877			0.35	1.54	---
6/08	-0.089	0.788			0.35	1.89	---
6/09	0.078	0.866			0.44	2.33	---
6/10	-0.002	0.564			0.36	2.69	0.352
6/11	0.005	0.869			0.60	3.29	0.505
6/12	-0.054	0.815			0.56	3.85	0.458
6/13	-0.325	0.490			0.28	4.13	0.294
6/14	-0.258	0.232			0.24	4.37	0.233
6/15	0.140	0.372			0.19	4.56	0.142
6/16	0.194	0.566			0.30	4.86	0.280
6/17	0.164	0.730			0.29	5.15	0.305
6/18	0.158	0.888			0.27	5.42	0.278
6/19	0.325	1.213			0.37	5.79	0.360
6/20	0.401	1.614			0.49	6.28	0.487
6/21	0.476	2.090			0.52	6.80	0.485
6/22	0.497	2.587			0.27	7.07	0.307
6/23	1.525	4.112			0.28	7.35	0.368
6/24	-0.381	3.731			0.36	7.71	0.235
6/25	0.899	4.630			0.25	7.96	0.255
6/26	0.109	4.739			0.49	8.45	0.440
6/27	0.655	5.394			0.42	8.87	0.463
6/28	0.212	5.606			0.40	9.27	0.437
6/29	0.287	5.893			0.43	9.70	0.448
6/30	0.140	6.033			0.42	10.12	0.437
7/01	0.379	6.412			0.55	10.67	0.520
7/02	0.419	6.831			0.53	11.20	0.543
7/03	0.188	7.019			0.29	11.49	0.318
7/04	0.229	7.248			0.29	11.78	0.322
7/05	0.230	7.478			0.37	12.15	0.328
7/06	0.236	7.714			0.41	12.56	0.355
7/07	0.209	7.923			0.20	12.76	0.327
7/08	0.151	8.074			0.56	13.32	0.382
7/09	0.242	8.316			0.23	13.55	0.360
7/10	0.198	8.514			0.50	14.05	0.533
7/11	0.396	8.910			0.65	14.70	0.557
7/12	0.416	9.326			0.53	15.23	0.577
7/13	0.308	9.634			0.46	15.69	0.527
7/14	0.305	9.939			0.24	15.93	0.110
7/15	0.126	10.065			0.27	16.20	0.317
7/16	0.253	10.318			---		0.483
7/17	0.282	10.600			0.45		0.480
7/18	0.374	10.974			0.59		0.610
7/19	0.499	11.473			0.51		0.520
7/20	0.427	11.900			0.49		0.602
7/21	0.324	12.224			0.53		0.515
7/22	0.299	12.523			0.43		0.537
7/23	0.378	12.901			0.47		0.602
7/24	0.265	13.166			0.42		0.378

TABLE XXI (Continued)

Date 1965	Lake Hefner Water Budget Daily in/day (d)	Cum inches	Stillwater Pond Daily in/day (e)	Cum inches	CRI Daily in/day	Cum inches	Class A Pan Daily in/day
7/25	0.233	0.233	0.27	0.27	0.73	0.73	0.418
7/26	0.143	0.376	0.26	0.53	0.13	0.86	0.258
7/27	0.197	0.573	0.31	0.84	0.42	1.28	0.395
7/28	0.355	0.928	0.24	1.08	0.23	1.51	0.222
7/29	0.354	1.282	0.30	1.38	0.27	1.78	0.332
7/30	0.118	1.400	0.30	1.68	0.38	2.16	0.355
7/31	0.376	1.776	0.24	1.92	0.20	2.36	0.160
8/01	0.233	2.009	0.31	2.23	0.25	2.61	0.318
8/02	0.234	2.243	0.25	2.48	0.45	3.06	0.420
8/03	0.373	2.616	0.37	2.85	0.53	3.59	0.545
8/04	0.428	3.044	0.42	3.27	---		0.532
8/05	0.463	3.507	0.36	3.63	---		---
8/06(f)	0.300	3.807	0.30	3.93	---		---
8/07	0.160	3.967	0.16	4.09	---		---
8/08	0.161	4.128	0.16	4.25	0.46		---
8/09	0.091	4.219	0.25	4.50	0.34		0.278
8/10	0.152	4.371	0.33	4.83	0.38		0.365
8/11	0.252	4.623	0.32	5.15	0.33		0.350
8/12	0.322	4.945	0.32	5.47	0.39		0.370
8/13	0.215	5.160	0.30	5.77	0.35		0.335
8/14	0.395	5.555	0.28	6.05	0.27		0.280
8/15	0.150	5.705	0.22	6.27	0.23		0.185
8/16	0.310	6.015	0.22	6.49	0.21		0.230
8/17	0.248	6.263	0.33	6.82	0.38		---
8/18	0.199	6.462	0.33	7.15	0.37		---
8/19	0.173	6.635	0.17	7.32	0.39		0.370
8/20	0.160	6.795	0.20	7.52	0.28		0.300
8/21	0.118	6.913	0.20	7.72	0.27		0.290
8/22	0.230	7.143	0.20	7.92	0.24		0.255
8/23	0.125	7.268	0.22	8.14	0.28		0.240
8/24	0.228	7.496	0.31	8.45	0.46		0.345
8/25	0.218	7.714	0.38	8.83	0.44		0.470
8/26	0.424	8.138	0.42	9.25	0.54		0.545
8/27	0.106	8.244	0.29	9.54	0.57		0.490
8/28	0.184	8.428	0.28	9.82	0.23		0.235
8/29	0.307	8.735	0.33	10.15	0.41		0.430
8/30	0.426	9.161	0.43	10.58	0.44		0.485
8/31	0.232	9.393	0.01	10.59	0.38		---
9/01	0.396	9.789	0.23	10.82	0.29		0.270
9/02	0.451	10.240	0.32	11.14	0.29		0.370
9/03	0.218	10.458	0.13	11.27	0.30		0.280
9/04	0.234	10.692	0.17	11.44	0.31		0.365
9/05	0.185	10.877	0.20	11.64	0.37		0.370
9/06	0.114	10.991	0.24	11.88	0 37		0.350
9/07	0.104	11.095	0.21	12.09	0.31		---
9/08	0.171	11.266	0.27	12.36	0.42		---
9/09	0.306	11.572	0.29	12.65	0.28		0.325
9/10	0.356	11.928	0.40	13.05	0.32		0.280

TABLE XXI (Continued)

Date 1965	Lake Hefner Water Budget Daily in/day (d)	Lake Hefner Water Budget Cum inches	Stillwater Pond Daily in/day (e)	Stillwater Pond Cum inches	CRI Daily in/day	CRI Cum inches	Class A Pan Daily in/day
9/11	0.187	12.115	0.19	13.24	0.29		0.347
9/12	0.280	12.395	0.23	13.47	0.49		0.583
9/13	0.344	12.739	0.30	13.77	0.44		0.457
9/14	0.427	13.166	0.34	14.11	---		0.290
9/15	0.384	13.550	0.36	14.47	---		0.803
9/16	0.499	14.049	0.38	14.85	---		---
9/17	0.532	14.581	0.10	14.95	---		---
9/18(f)	0.020	14.601	0.02	14.97	---		---
9/19	0.060	14.661	0.06	15.03	---		---
9/20	0.030	14.691	0.03	15.06	---		---
9/21	0.150	14.841	0.15	15.21	---		---
9/22	0.170	15.011	0.17	15.38	---		---
9/23	0.217	15.228	0.37	15.75	0.49		---
9/24	0.352	15.580	0.13	15.88	0.15		0.077
9/25	0.346	15.926	0.15	16.03	0.07		0.097
9/26	0.137	16.063	0.13	16.16	0.17		0.203
9/27	0.216	16.279	0.15	16.31	0.23		0.287
9/28	0.232	16.511	0.15	16.46	0.26		0.290
9/29	0.410	16.921	0.26	16.72	0.40		0.290
9/30	0.364	17.285	0.23	16.95	0.04		0.083
10/01	0.367	17.652	0.13	17.08	0.24		0.183
10/02	0.158	17.810	0.12	17.20	0.49		0.130
10/03	0.140	17.950	0.06	17.26	-0.23		0.103
10/04	0.149	18.099	0.08	17.34	0.05		0.063
10/05	0.083	18.182	0.15	17.49	0.13		0.097
10/06	0.103	18.285	0.08	17.57	0.18		0.240
10/07	0.090	18.375	0.22	17.79	0.12		0.127
10/08	0.102	18.477	0.11	17.90	0.16		0.177
10/09	0.170	18.647	0.12	18.02	0.17		0.210
10/10	0.139	18.824	0.15	18.17	0.42		0.437
10/11	0.450	19.274	0.24	18.41	0.18		0.143
10/12	0.152	19.426	0.15	18.56	0.22		0.197
10/13	0.186	19.612	0.10	18.66	0.15		0.193
10/14	0.053	19.665	0.07	18.73	0.31		0.323
10/15	0.121	19.786	0.06	18.79	0.06		0.097
10/16	0.022	19.808	0.10	18.89	0.25		0.187
10/17	0.104	19.912	0.18	19.07	0.30		0.297
10/18	0.124	20.036	0.14	19.21	0.09		0.103
10/19	0.130	20.166	0.20	19.41	0.23		0.227
10/20	0.247	20.413	0.33	19.74	0.27		0.207
10/21	0.449	20.862	0.18	19.92	0.22		0.237
10/22	0.258	21.120	0.13	20.05	0.15		0.087
10/23	0.073	21.193	0.11	20.16			
10/24			0.11	20.27			
10/25			0.10	20.37			
10/26							

(a) Water budget evaporation was measured from 2400-2400.

(b) Evaporation from CRI and pan was measured from 0900-0900.

(c) -- Indicates missing record.

(d) Cumulative evaporations are listed beginning on July 25 because of missing data before that date.

(e) Pond evaporation was measured from 0800-0800.

(f) Lake evaporation estimates from pond evaporation for August 6 and September 18-22, 1965.

TABLE XXII

1966 SUMMARY TABLE OF DAILY AND CUMULATIVE EVAPORATION FROM LAKE, POND, CRI, UNTREATED TANKS, AND UNTREATED CLASS A PAN

Date 1966	Lake Hefner Water Budget Daily in/day	Lake Hefner Water Budget Cum inches	15 Foot Tank Daily in/day	15 Foot Tank Cum inches	9 Foot Tank Daily in/day	9 Foot Tank Cum inches	Stillwater Pond Daily in/day	Stillwater Pond Cum inches	CRI Daily in/day	CRI Cum inches	Class A Pan Daily in/day
6/14	0.189(a)	0.189							0.61(d)		0.60
6/15	0.268	0.457							---		---
6/16	0.110	0.567							0.15		0.30
6/17	0.206	0.773							0.26		0.17
6/18	0.175	0.948							0.35		0.28
6/19	0.171	1.119							0.26		0.32
6/20	0.277	1.396							0.53		0.41
6/21	0.244	1.640							0.39		0.47
6/22	0.386	2.026							0.45		0.49
6/23	0.271	2.297							0.36		0.47
6/24	0.421	2.718							0.45		0.52
6/25	0.229	2.947							0.47		0.41
6/26	0.168	3.115							0.38		0.42
6/27	0.274	3.389							0.50		0.54
6/28	0.298	3.687							0.58		0.53
6/29	0.200	3.804							0.43		0.50
6/30	0.128	3.932							0.33		0.38
7/01	0.268	4.200							0.47		0.69
7/02	0.157	4.357	0.32(b)	0.32	0.25(c)	0.25			0.34		0.29
7/03	0.230	4.587	0.30	0.62	0.30	0.55			0.38		0.42
7/04	0.227	4.814	0.46	1.08	0.42	0.97			0.45		0.52
7/05	0.299	5.113	0.54	1.62	0.43	1.40			0.68		0.72
7/06	0.241	5.354	0.38	2.00	0.36	1.76			0.42		0.36
7/07	0.254	5.608	0.42	2.42	0.35	2.11			0.35		0.50
7/08	0.343	5.951	0.34	2.76	0.37	2.48			0.46		0.49
7/09	0.298	6.249	0.47	3.23	0.41	2.89			0.51		0.59
7/10	0.318	6.567	0.41	3.64	0.48	3.37			0.58		0.64
7/11	0.456	7.023	0.56	4.20	0.51	3.88			0.61		0.70
7/12	0.395	7.418	0.40	4.60	0.47	4.35			0.73		0.65
7/13	0.820	8.238	0.50	5.10	0.47	4.82			0.47		0.62
7/14	0.536	8.774	0.32	5.42	0.40	5.22			0.37		0.55
7/15	0.257	9.031	0.31	5.73	0.42	5.64			0.37		0.39
7/16	0.235	9.266	0.26	5.99	0.34	5.98			0.34		0.39
7/17	0.285	9.551	0.36	6.35	0.40	6.38			0.55		0.46
7/18	0.493	10.044	0.46	6.81	0.62	7.00			0.49		0.61
7/19	0.928	10.972	0.48	7.29	0.30	7.30			0.47		---
7/20	0.729	11.701	0.34	7.63	0.22	7.52			0.44		---
7/21	0.925	12.626	0.20	7.83	0.13	7.65			0.00		---
7/22	0.549	13.175	0.15	7.98	0.26	7.91			0.29		---
7/23	-0.000	13.175	0.31	8.29	0.17	8.08			0.30		---
7/24	0.135	13.310	0.15	8.44	0.10	8.18			0.08		0.18
7/25	0.157(e)	0.157	0.37	0.37	0.30	0.30	0.41	0.41	0.32	0.32	0.39
7/26	0.340	0.497	0.30	0.67	0.38	0.68	0.41	0.82	0.47	0.79	0.50
7/27	0.336	0.833	0.45	1.12	0.43	1.11	0.35	1.17	0.62	1.41	0.49
7/28	0.190	1.023	0.21	1.33	0.19	1.30	0.23	1.40	0.25	1.66	0.32
7/29	0.193	1.216	0.22	1.55	0.31	1.61	0.33	1.73	0.25	1.91	0.40
7/30	0.060	1.276	0.19	1.74	0.20	1.81	0.26	1.99	0.81	2.72	---
7/31	0.148	1.424	0.27	2.01	0.32	2.13	0.27	2.26	0.53	3.25	0.40
8/01	0.296	1.720	0.28	2.29	0.39	2.52	0.37	2.63	0.36	3.61	0.41
8/02	0.317	2.037	0.48	2.77	0.36	2.88	0.39	3.02	0.44	4.05	0.39
8/03	0.485	2.522	0.29	3.06	0.28	3.16	0.26	3.28	0.22	4.27	0.33
8/04	0.278	2.800	0.44	3.50	0.26	3.42	0.22	3.50	0.43	4.70	0.35
8/05	0.213	3.013	0.25	3.75	0.22	3.64	0.19	3.69	0.17	4.87	0.26
8/06	0.327	3.340	0.26	4.01	0.31	3.95	0.27	3.96	0.47	5.34	0.40
8/07	0.165	3.505	0.23	4.24	0.27	4.22	0.24	4.20	0.18	5.52	0.35
8/08	0.182	3.687	0.28	4.52	0.30	4.52	0.21	4.41	0.43	5.95	0.30
8/09	0.297	3.984	0.37	4.89	0.37	4.89	0.31	4.72	0.51	6.46	---
8/10	0.296	4.280	0.21	5.10	0.19	5.08	0.27	4.99	0.23	6.69	---

TABLE XXII (Continued)

Date 1966	Lake Hefner Water Budget Daily in/day	Lake Hefner Water Budget Cum inches	15 Foot Tank Daily in/day	15 Foot Tank Cum inches	9 Foot Tank Daily in/day	9 Foot Tank Cum inches	Stillwater Pond Daily in/day	Stillwater Pond Cum inches	CRI Daily in/day	CRI Cum inches	Class A Pan Daily in/day
8/11	0.234	4.514	0.21	5.31	0.22	5.30	0.13	5.12	0.11	6.80	0.18
8/12	0.231	4.745	0.22	5.53	0.28	5.58	0.20	5.32	0.41	7.21	0.26
8/13	0.043	4.788	0.15	5.68	0.13	5.71	0.14	5.46	0.08	7.29	0.18
8/14	0.189	4.977	0.22	5.90	0.26	5.97	0.14	5.60	0.26	7.55	0.30
8/15	0.304	5.281	0.34	6.24	0.35	6.32	0.28	5.88	0.54	8.09	0.49
8/16	0.219	5.500	0.35	6.59	0.38	6.70	0.29	6.17	0.36	8.45	0.52
8/17	0.259	5.759	0.35	6.94	0.43	7.13	0.34	6.51	0.48	8.93	0.54
8/18	0.060	5.819	0.23	7.17	0.23	7.36	0.20	6.71	0.30	9.23	---
8/19	0.145	5.964	0.20	7.37	0.23	7.59	0.24	6.95	0.64	9.87	---
8/20	0.164	6.128	0.28	7.65	0.24	7.83	0.24	7.19	0.10	9.97	0.37
8/21	0.084	6.212	0.20	7.85	0.17	8.00	0.24	7.43	0.19	10.16	0.16
8/22	0.320	6.532	0.18	8.03	0.14	8.14	0.19	7.62	0.18	10.34	---
8/23	0.300	6.832	0.18	8.21	0.14	8.28	0.12	7.74	0.18	10.52	---
8/24	0.168	7.000	0.09	8.30	0.10	8.38	0.13	7.87	0.02	10.54	0.11
8/25	0.230	7.230	0.14	8.44	0.16	8.54	0.17	8.04	0.19	10.73	0.26
8/26	0.297	7.527	0.25	8.69	0.29	8.83	0.26	8.30	0.40	11.13	0.32
8/27	0.239	7.766	0.19	8.88	0.22	9.05	0.17	8.47	0.14	11.27	0.22
8/28	0.147	7.913	0.13	9.01	0.15	9.20	0.18	8.65	0.20	11.47	0.23
8/29	0.214	8.127	0.10	9.11	0.12	9.32	0.16	8.81	0.18	11.65	0.21
8/30	0.056	8.183	0.19	9.30	0.22	9.54	0.07	8.88	0.36	12.01	---
8/31	0.129	8.312	0.16	9.46	0.18	9.72	0.05	8.93	0.18	12.19	0.24
9/01	0.188	8.500	0.16	9.62	0.18	9.90	0.16	9.09	0.18	12.37	0.22
9/02	0.122	8.622	0.20	9.82	0.23	10.13	0.12	9.21	0.36	12.73	0.31
9/03	0.098	8.720	0.21	10.03	0.24	10.37	0.12	9.33	0.48	13.21	---
9/04	0.068	8.788	0.07	10.10	0.08	10.45	0.12	9.45	0.12	13.33	0.14
9/05	0.002	8.790	0.30	10.40	0.34	10.79	0.12	9.57	0.31	13.64	0.25
9/06	0.335	9.125	0.25	10.65	0.27	11.06	0.25	9.82	0.32	13.96	0.23
9/07	0.154	9.279	0.21	10.86	0.22	11.28	0.19	10.01	0.19	14.15	0.24
9/08	0.185	9.464	0.20	11.06	0.19	11.47	0.19	10.20	0.18	14.33	0.15
9/09	0.146	9.610	0.11	11.17	0.12	11.59	0.14	10.34	0.17	14.50	0.16
9/10	0.114	9.724	0.19	11.36	0.18	11.77	0.17	10.51	0.15	14.65	0.19
9/11	0.093	9.817	0.09	11.45	0.12	11.89	0.12	10.63	0.14	14.79	0.08
9/12	0.134	9.951	0.11	11.56	0.08	11.97	0.12	10.75	0.14	14.93	---
9/13	0.102	10.053	0.06	11.62	0.25	12.22	0.17	10.92	0.50	15.43	---
9/14	0.191	10.244	0.25	11.87	0.23	12.45	0.29	11.21	0.23	15.66	0.29
9/15	0.266	10.510	0.06	11.93	0.05	12.50	0.14	11.35	0.08	15.74	---
9/16	0.021	10.531	0.03	11.96	0.02	12.52	0.09	11.44	0.02	15.76	---
9/17	0.291	10.822	(f)				0.09	11.53	0.13	15.89	
9/18	0.141	10.963	0.21	12.17	0.20	12.72	0.09	11.62	0.13	16.02	0.26
9/19	0.339	11.302					0.16	11.78	0.17	16.19	
9/20	0.237	11.539					0.17	11.95			
9/21	0.098	11.637	0.32	12.49	0.30	13.02	0.16	12.11	0.19	16.38	0.44
9/22	0.296	11.933					0.19	12.30	0.22	16.60	
9/23	0.035	11.968	0.31	12.80	0.34	13.36	0.12	12.42	0.22	16.82	0.42
9/24	0.310	12.278	0.23	13.03	0.23	13.59	0.23	12.65	0.19	17.01	0.35
9/25	0.176	12.454	0.26	13.29	0.27	13.86	0.22	12.87	0.34	17.35	0.34
9/26	0.052	12.506	0.16	13.45	0.12	13.98	0.14	13.01	0.26	17.61	0.20
9/27	0.297	12.803	0.11	13.56	0.23	14.21	0.10	13.11	0.27	17.88	---
9/28	0.091	12.894					0.14	13.25	0.10	17.98	
9/29	0.167	13.061	0.26	13.82	0.23	14.44	0.28	13.53	0.19	18.17	0.30
9/30	0.434	13.495					0.18	13.71	0.23	18.40	
10/01	0.192	13.687	0.46	14.28	0.41	14.85	0.20	13.91	0.23	18.63	0.38
10/02	0.656	14.343	0.28	14.56	0.24	15.09	0.21	14.12	0.27	18.90	0.28
10/03	0.157	14.500	0.19	14.75	0.23	15.32	0.27	14.39	0.28	19.18	0.29
10/04	0.428	14.928	0.21	14.96	0.23	15.55	0.15	14.54	0.29	19.47	0.22
10/05	0.057	14.985					0.15	14.69	0.15	19.62	
10/06	0.141	15.126	0.25	15.21	0.24	15.79	0.20	14.89	0.16	19.78	0.31
10/07	0.225	15.351					0.20	15.09	0.24	20.02	
10/08	0.164	15.515	0.36	15.57	0.41	16.20	0.19	15.28	0.24	20.26	0.47
10/09	0.100	15.615	0.11	15.68	0.15	16.35	0.19	15.47	0.13	20.39	0.23
10/10	0.197	15.812					0.13	15.60	0.28	20.67	
10/11	0.205	16.017	0.41	16.09	0.42	16.77	0.19	15.79	0.28	20.95	0.53
10/12	0.038	16.055	0.11	16.20	0.14	16.91	0.04	15.83	0.18	21.13	0.23
10/13	0.073	16.128	0.11	16.31	0.11	17.02	0.09	15.92	0.10	21.23	0.24
10/14	0.326	16.454					0.07	16.62	0.50	21.73	---
10/15	0.404	16.858	0.80	17.11	0.77	17.79	0.18	16.80	0.50	22.23	0.73

TABLE XXII (Continued)

Date 1966	Lake Hefner Water Budget Daily in/day	Lake Hefner Water Budget Cum inches	15 Foot Tank Daily in/day	15 Foot Tank Cum inches	9 Foot Tank Daily in/day	9 Foot Tank Cum inches	Stillwater Pond Daily in/day	Stillwater Pond Cum inches	CRI Daily in/day	CRI Cum inches	Class A Pan Daily in/day
10/16	0.140	16.998	0.15	17.26	0.13	17.92	0.17	16.97	0.03	22.26	0.14
10/17							0.03	17.00	0.03	22.29	---
10/18	0.195	17.193	0.16	17.42	0.17	18.09	0.21	17.21	0.03	22.32	---
10/19							0.13	17.34	0.24	22.56	
10/20	0.773	17.966	0.40	17.82	0.34	18.43	0.23	17.57	0.25	22.81	0.36
10/21							0.24	17.81	0.24	23.05	
10/22	0.803	18.769	0.45	18.27	0.47	18.90	0.13	17.94	0.25	23.30	0.56
10/23	0.121	18.890	0.11	18.38	0.12	19.02	0.14	18.08	0.16	23.46	0.14
10/24							0.08	18.16	0.16	23.62	
10/25	0.344	19.234	0.18	18.56	0.20	19.22	0.09	18.25	0.16	23.78	0.29
10/26							0.09	18.34	0.16	23.94	
10/27	0.121	19.355	0.21	18.77	0.25	19.47	0.17	18.51	0.16	24.10	0.35
10/28							0.13	18.64	0.27	24.37	
10/29	0.254	19.609	0.35	19.12	0.36	19.83	0.11	18.75	0.27	24.64	0.44
10/30							0.11	18.86	0.24	24.88	
10/31							0.24	19.10	0.23	25.11	
11/01	0.543	20.152	0.57	19.69	0.60	20.43	0.29	19.39	0.23	25.34	0.62
11/02							0.11	19.50	0.12	25.46	
11/03	0.544	20.696	0.31	20.00	0.25	20.68	0.11	19.61	0.12	25.58	0.15
11/04							0.05	19.66	0.08	25.66	
11/05	0.205	20.901	0.13	20.13	0.12	20.80	0.05	19.71	0.08	25.74	0.22
11/06	0.014	20.915	0.04	20.17	0.01	20.81	0.05	19.76	0.04	25.78	0.11
11/07							0.04	19.80	0.25	26.03	
11/08	0.061	20.976	0.20	20.37	0.34	21.15	0.27	20.07	0.25	26.28	0.63
11/09									0.19	26.47	
11/10									0.19	26.66	
11/11	0.527	21.503	0.59	20.96	0.54	21.69			0.19	26.85	0.52
11/12	0.178	21.681	0.11	21.07	0.09	21.78					0.09
11/13											
11/14											
11/15											
11/16	0.380	22.061	0.45	21.52	0.46	22.24					0.75
11/17											
11/18											
11/19	0.314	22.375	0.42	21.94	0.48	22.72					0.67
11/20	0.099	22.474	0.06	22.00	0.07	22.79					0.12
11/21											
11/22											
11/23											
11/24											
11/25											
11/26											
11/27	0.968	23.442	0.73	22.73	0.86	23.65					1.19
11/28											
11/29											
11/30											
12/01											
12/02											
12/03											
12/04	1.404	24.846	0.76	23.49	0.57	24.22					0.53

(a) Water budget evaporation was measured from 2400-2400 until October 15, 1966. After that date it was measured from 1600-1600.

(b) Evaporation from tanks and pans was measured from 0900-0900 (lags water budget evaporation 9 hours) until September 19, 1966. After that date it was measured from 1600-1600 and thus leads water budget evaporation by 8 hours until October 16, 1966, when all pan, tank, and lake evaporation measurements were placed on a 1600-1600 basis.

(c) Pond evaporation was measured from 0800-0800.

(d) -- indicates missing record

(e) Cumulative evaporations are listed beginning on July 25 because of missing data before that date.

(f) A blank indicates that no measurement was taken on that particular day. The total evaporation between measurements was recorded at the time of the next measurement.

APPENDIX F

COMPUTATION OF MASS TRANSFER COEFFICIENT N FOR THE LAKE, 15-FOOT TANK, AND 9-FOOT TANK

TABLE XXIII

COMPUTATION OF MASS TRANSFER COEFFICIENT N FOR THE LAKE, 15-FOOT TANK, AND 9-FOOT TANK

TSP	Lake Hefner				South Station		15-Foot Tank			9-Foot Tank		
	Raft Wind Speed	Water Budget Evap	Vapor Pressure Deficit	Mass Transfer Coeff	2-Meter Wind Speed	Wind Speed Ratio	Evap	Vapor Pressure Deficit	Mass Transfer Coeff	Evap	Vapor Pressure Deficit	Mass Transfer Coeff
	u	E_{wb}	$(e_o-e_a)_L$	N	u_{ss-2}	u/u_{ss-2}	E_{15}	$(e_o'-e_a)_{15}$	N_{15}	E_o	$(e_o'-e_a)_9$	N_9
	MPH	cm/day	mb	(a)	MPH		cm/day	mb	(a)	cm/day	mb	(a)
1965												
1	13.35				9.45	1.42						
2	8.61				---	---						
3	12.26				8.15	1.51						
4	14.51				9.89	1.47						
5	10.98	0.672	13.75	2.58	7.34	1.50						
6	11.32	0.718	13.66	2.69	7.71	1.47						
7	11.00	0.836	16.72	2.63	7.63	1.44						
8	8.91	0.693	12.40	3.63	6.08	1.46						
9	8.43	0.796	19.35	2.83	5.24	1.60						
10	8.85	0.584	12.99	2.94	5.25	1.70						
11	9.99	0.532	7.71	4.01	---	---						
12	12.85	0.643	8.85	3.28	8.25	1.56						
13	13.39	0.670	11.81	2.45	8.29	1.62						
15	16.58	0.881	13.21	2.33	9.13	1.82						
16	11.51	0.750	12.42	3.05	8.20	1.40						
17	6.32	0.299	10.80	2.55	3.64	1.73						
18	12.96	0.488	8.36	2.63	8.68	1.50						
Average (Excluding TSP's 2, 11)(b)	11.55				7.53	1.53						
Average (TSP's 5-12, 15-18)(d)				2.93								
1966												
1	10.01	0.526	14.06	2.17								
2	14.58	0.716	10.19	2.80								
3	9.35	0.574	14.44	2.46								
6	10.80			(c)	7.72	1.40	0.719	14.11	3.83	0.790	14.09	4.21
7	7.40				4.89	1.51	0.759	17.21	5.24	0.721	17.09	5.01
8	12.00				7.92	1.52	0.658	12.58	3.87	0.729	12.32	4.34
9	10.22	0.574	14.61	2.25	6.43	1.59	0.495	11.82	3.79	0.490	11.84	3.75
10	11.40				7.77	1.47	0.373	8.65	3.23	0.429	9.25	3.47
11	6.40				3.76	1.70	0.452	13.76	5.09	0.549	12.09	7.04
12	8.12	0.409	11.90	2.47	6.06	1.34	0.295	9.47	3.00	0.264	7.44	3.42
13	8.30	0.445	12.74	2.45	5.93	1.40	0.424	11.91	3.51	0.456	11.38	4.00
14	12.76	0.754	12.45	2.77	8.99	1.42	0.505	9.20	3.54	0.490	8.75	3.65
15	14.90	0.480	8.50	2.22	11.22	1.33	0.546	8.55	3.34	0.574	8.48	3.53
16					9.69		0.422	8.31	3.08	0.404	7.16	3.43
17					5.76		0.307	8.39	3.74	0.338	8.40	4.11
18					7.98		0.366	7.17	3.77	0.353	6.06	4.31
Avg. (TSP's 9,12-15) (d)	10.86			2.43	7.73	1.41			3.44			3.67
Avg. (TSP's 6-18)									3.77			4.18
Avg. (TSP's 6-15)(b)	10.23				7.07	1.45						
Avg. 1965 and 1966 (b)	11.02				7.34	1.50						

(a) Mass transfer coefficient N = cal/cm^2 day mph mb
(b) Excludes TSP's with missing wind data
(c) Water Budget "N" values not computed for treated TSP's 4, 6, 7, 8, 10, and 11.
(d) Excludes treated TSP's and periods of missing lake data

APPENDIX G

LIST OF SYMBOLS

LIST OF SYMBOLS

Symbol	Description
A	Surface area, ft^2
c	Specific heat of water, cal/gm °C
C	Fraction of the water surface covered with a film
C_1, C_2	Coefficients
c_a	Vapor concentration above the boundary layer, gm/cm^3
c_o	Vapor concentration at water surface, gm/cm^3
c_p	Specific heat of air at constant pressure, cal/gm °C
dq/dz	Moisture gradient at 75 cm above the surface, 1/cm
dt/dz	Temperature gradient at 75 cm above the surface, °C/cm
E	Evaporation, in/day
E	evaporation, cm/day
E	evaporation, cm/3 hrs (Equation 3)
E	evaporation, in (Equation 1)
E_{eb}	Lake energy budget evaporation, in/day
E_p	Pan evaporation, in/day
E_t	Evaporation from sunken tank, in/day
E_{uswb}	Evaporation predicted by the Weather Bureau method, in/day
E_{wb}	Lake water budget evaporation, in/day
E_9, E_{15}	Evaporation from 9-foot and 15-foot tanks, in/day
E_x	Local evaporation rate, gm/cm^2 sec

Symbol	Description
ER	Evaporation reduction, percent
ET	Evapotranspiration, gms/cm^2 sec
e_a	Vapor pressure of the air at 2-meter height, mb
e''_a	Vapor pressure of the air, inches of mercury
e_o	Saturation vapor pressure at the water surface temperature, mb
e'_o	Saturation vapor pressure at the water surface temperature of a sunken tank, mb
e''_o	Saturation vapor pressure over water, inches of mercury
e_s	Vapor pressure of the air at the dew point, inches of mercury
e_8	Vapor pressure of the air at 8-meter height, mb
F	Evaporation reduction factor, percent
G	Soil heat flux, cal/cm^2 sec
H	Convective heat flux, cal/cm^2 sec
I	Inflow from streams and rainfall, in.
K	Heat transfer coefficient, cal/cm^2 day mph °C
K_d	Eddy diffusivity for water vapor, cm^2/sec
K_h	Eddy conductivity for heat, cm^2/sec
L	Latent heat of vaporization, cal/gm °C
M	Film movement, miles/hour
N	Mass transfer coefficient, cal/cm^2 day mph mb
n	Mass transfer coefficient, cm/day mph mb
n_1	Mass transfer coefficient for sunken tank, cm/day mph mb
O	Outflow, in
P	Atmospheric pressure, mb

Symbol	Description
Pr	Prandtl number (Pr = 0.7 for air)
q	Absolute humidity of the air, gms/gm
q''_x	Local heat flux at the surface of a flat plate
Q_a	Incoming long-wave radiation from the atmosphere, cal/cm^2 day
Q_{ar}	Reflected long-wave radiation, cal/cm^2 day
Q_{bs}	Long-wave radiation emitted by the body of water, cal/cm^2 day
Q_e	Energy used in evaporation, cal/cm^2 day
Q_h	Energy conducted from the body of water as sensible heat, cal/cm^2 day
Q_{in}	Net incoming radiation, $(Q_s - Q_r + Q_a - Q_{ar})$, cal/cm^2 day
Q_{ir}	Difference between incident and reflected radiation (all wave)
Q_n	Net radiation entering the body of water, $(Q_s - Q_r + Q_a - Q_{ar} - Q_{bs})$, cal/cm^2 day
Q_o	Increase in energy stored in the body of water, cal/cm^2 day
Q_v	Net energy advected into the body of water, cal/cm^2 day
Q_w	Energy advected by the evaporated water, cal/cm^2 day
Q_s	Short-wave solar radiation incident to the water surface, cal/cm^2 day
Q_r	Reflected solar radiation, cal/cm^2 day
R	Correlation coefficient
R	Bowen ratio, Q_h/Q_e
RH	Relative humidity, percent
Re_x	Reynolds number
Re_ξ	Reynolds number based on unheated length of flat plate

Symbol	Description
R_n	Net radiation, cal/cm^2 sec
S	Change in reservoir storage, in
T	Pan water surface temperature, °F
T	Pan water surface temperature, °C (Equation 16)
T_a	Air temperature at the 2-meter height, °C
T_a	Air temperature, °F (Equation 10)
T_a	Air temperature at the 2-meter height, °K (Equation 11)
T_e	Temperature of the evaporated water, °C
T_o	Water surface temperature, °C
t	Air temperature
t_o	Temperature of the leeward portion of a flat plate
t_∞	Air temperature above the boundary layer
U	Velocity of the air at an elevation Y, cm/sec (Equation 22)
U	8-meter wind speed, mph (Equation 29)
U_o	2-meter wind speed, mph
U_∞	Velocity of the air above the boundary layer, cm/sec
u	2-meter lake wind speed, mph
u_p	Pan wind movement at 24 inches above the ground, miles/day
u_{ss-2}	2-meter wind speed at the south instrument station, mph
u_4	4-meter lake wind speed, miles/day
u_8	8-meter wind speed, knots
W	Ground wind speed, mph
X	Horizontal distance from leading edge of a flat plate
Y	Vertical distance from a flat plate

Symbol	Description
Z, Z_o	Height above a reference plane or surface, meters (Equation 29)
z	Height, cm
α_p	Proportion of advected energy utilized for evaporation
$\delta(X)$	Thickness of the velocity boundary layer
$D(X)$	Thickness of the thermal boundary layer
$\delta_w(X)$	Thickness of the vapor concentration boundary layer
Δ	First derivative of e_o versus T_o, mb/°C
ΔT	Difference between water surface temperatures of treated and untreated evaporation pans, °C
ε	Emissivity of the water surface
γ	Psychrometric constant, mb/°C
ρ	Density of air, gms/cm^3
σ	Stefan-Boltzman constant, 1.171×10^{-7} cal/cm^{2}day °K^4
σ	Stefan-Boltzman constant, 7.8×10^{-11}, equivalent inches of evaporation/cm^{2}day °K^4
ξ	Length of the unheated portion of the flat plate
ν	Kinematic viscosity, cm^2/sec

VITA

James Butler Allen

Candidate for the Degree of

Doctor of Philosophy

Thesis: AN ANALYSIS OF EVAPORATION AT LAKE HEFNER, 1965-1966, BASED ON THE WATER BUDGET, ENERGY BUDGET, AND EVAPORATION TANKS

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